

METAL COMPOUND, AND CATALYST COMPONENT AND CATALYST FOR  
ADDITION POLYMERIZATION, AND PROCESS FOR PRODUCING ADDITION  
POLYMER

5

Field of the Invention

The present invention relates to a metal compound; a  
catalyst component for addition polymerization comprising the  
metal compound; a catalyst for addition polymerization using  
10 the catalyst component for addition polymerization; and a  
process for producing an addition polymer.

Background of the Invention

Since olefin polymers such as polypropylene and  
15 polyethylene are excellent in mechanical properties and  
chemical resistance, and excellent in balance between those  
properties and economical efficiency, they have been widely  
used in various fields such as a packaging field. These olefin  
polymers have conventionally been produced by polymerizing  
20 an olefin using a conventional type solid catalyst (multi-site  
catalyst), which combines a solid catalyst component obtained  
by using a metal compound of the Group IV such as titanium  
trichloride or titanium tetrachloride, with a metal compound  
of the Group 13 represented by an organoaluminum compound.

25 However, as a catalyst providing addition polymers having  
less stickiness and more excellent strength than those produced  
by the conventional catalyst, a so-called single site catalyst  
prepared by combining a catalyst component such as a metallocene  
complex or half metallocene complex with a co-catalyst  
30 component for activation such as an aluminoxane, and

tri(n-butyl)ammonium tetrakis(pentafluorophenyl)borate, was proposed and with respect to the single site catalyst, improvements for using it in an industrial scale have been studied (e.g. JP 58-19309 A, US5621126, US5153157).

5 Further, recently, a compound prepared by contacting diethylzinc and pentafluorophenol has been developed as a co-catalyst component for activation, and a catalyst prepared by contacting said co-catalyst component with the metallocene complex has been proposed as a high activity catalyst (e.g.  
10 US6586356).

However, according to the inventor's studies, when an olefin is addition-polymerized with the above-mentioned catalyst, its polymerization activity is not completely satisfactory.

#### 15 Summary of the Invention

Under the above-situations, an object of the present invention is to provide a metal compound used as a catalyst component of a catalyst for addition polymerization having  
20 an excellent polymerization activity; a catalyst component for addition polymerization comprising the metal compound; a catalyst for addition polymerization using the catalyst component for addition polymerization; and a process for producing an addition polymer using the catalyst for addition  
25 polymerization.

Namely, the present invention is a metal compound obtained by a process comprising the step of contacting the following components (a) to (c), wherein the amount of the component (b) contacted is from 0.1 to 8 mol, and the amount  
30 of the component (c) contacted is from 0.5 to 8 mol, per 1

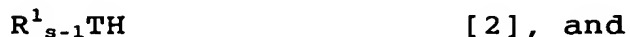
mol of the component (a), respectively:

(a) a compound represented by the following formula [1]



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(b) a compound represented by the following formula [2]



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(c) a compound represented by the following formula [3],



wherein  $M^1$  is a metal atom of the Groups 12 to 15 in the periodic  
 15 table or a boron atom;  $r$  is a valence of  $M^1$ ;  $L^1$  is a hydrogen  
 atom, a halogen atom, a hydrocarbon group or a hydrocarbon  
 oxy group, and when two or more  $L^1$ 's exist, they may be the  
 same or different from one another;  $T$  is a non-metal atom of  
 the Group 15 or 16 in the periodic table;  $s$  is a valence of  
 20  $T$ ;  $R^1$  is an electron-withdrawing group or an  
 electron-withdrawing group-containing group, and when two or  
 more  $R^1$ 's exist, they may be the same or different from one  
 another;  $n$  is the number of from 2 to 4;  $J$  is a non-metal atom  
 of the Group 14 in the periodic table; and  $R^2$  represents a  
 25 hydrocarbon group, and when two or more  $R^2$ 's exist, they may  
 be the same or different from one another.

Also, the present invention is a catalyst component for  
 addition polymerization comprising the above-mentioned metal  
 compound.

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Further, the present invention is a catalyst for addition

polymerization obtained by a process comprising the step of contacting the above-mentioned catalyst component for addition polymerization with a compound (B) of a metal selected from the group consisting of metals of the Groups 3 to 11 and lanthanide series, and optionally an organoaluminum compound (C).

Still further, the present invention is a process for producing an addition polymer comprising the step of polymerizing an addition polymerizable monomer in the presence of the above-mentioned catalyst for addition polymerization.

#### Detailed Description of the Invention

Examples of  $M^1$  in the formula [1] are a zinc atom, a cadmium atom, a mercury atom, an aluminum atom, a gallium atom, an indium atom, a thallium atom, a germanium atom, a tin atom, a lead atom, an antimony atom, a bismuth atom and a boron atom.  $M^1$  is preferably a zinc atom, an aluminum atom, a gallium atom, an indium atom, a thallium atom, an antimony atom, a bismuth atom or a boron atom, and more preferably an aluminum atom, a bismuth atom or a boron atom. In the formula [1],  $r$  is an integer of from 2 to 5, and preferably 3.

Examples of the halogen atom of  $L^1$  are a fluorine atom, a chlorine atom, a bromine atom and an iodine atom. The hydrocarbon group of  $L^1$  is preferably an alkyl group, an aryl group or an aralkyl group. The hydrocarbon oxy group of  $L^1$  is preferably an alkoxy group or an aryloxy group.

Examples of the above-mentioned alkyl group are a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, a tert-butyl group, an

isobutyl group, a n-pentyl group, a neopentyl group, a n-hexyl group, a n-octyl group, a n-decyl group, a n-dodecyl group, a n-pentadecyl group and a n-eicosyl group.

These alkyl groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom. Examples of the alkyl group substituted with the halogen atom are a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, a chloromethyl group, a dichloromethyl group, a trichloromethyl group, a bromomethyl group, a dibromomethyl group, a tribromomethyl group, an iodomethyl group, a diiodomethyl group, a triiodomethyl group, a fluoroethyl group, a difluoroethyl group, a trifluoroethyl group, a tetrafluoroethyl group, a pentafluoroethyl group, a chloroethyl group, a dichloroethyl group, a trichloroethyl group, a tetrachloroethyl group, a pentachloroethyl group, a bromoethyl group, a dibromoethyl group, a tribromoethyl group, a tetrabromoethyl group, a pentabromoethyl group, a perfluoropropyl group, a perfluorobutyl group, a perfluoropentyl group, a perfluorohexyl group, a perfluorooctyl group, a perfluorododecyl group, a perfluoropentadecyl group, a perfluoroeicosyl group, a perchloropropyl group, a perchlorobutyl group, a perchloropentyl group, perchlorohexyl group, a perchlorooctyl group, a perchlorododecyl group, a perchloropentadecyl group, a perchloroeicosyl group, a perbromopropyl group, a perbromobutyl group, a perbromopentyl group, a perbromohexyl group, a perbromooctyl group, a perbromododecyl group, a perbromopentadecyl group and a perbromoeicosyl group.

The alkyl group as  $L^1$  is preferably an alkyl group having 1 to 20 carbon atoms, and more preferably a methyl group, an

ethyl group, an isopropyl group, a n-butyl group, a tert-butyl group or an isobutyl group.

Examples of the aryl group as  $L^1$  are a phenyl group, a 2-tolyl group, a 3-tolyl group, a 4-tolyl group, a 2,3-xylyl group, a 2,4-xylyl group, a 2,5-xylyl group, a 2,6-xylyl group, a 3,4-xylyl group, a 3,5-xylyl group, a 2,3,4-trimethylphenyl group, a 2,3,5-trimethylphenyl group, a 2,3,6-trimethylphenyl group, a 2,4,6-trimethylphenyl group, a 3,4,5-trimethylphenyl group, a 2,3,4,5-tetramethylphenyl group, a 2,3,4,6-tetramethylphenyl group, a 2,3,5,6-tetramethylphenyl group, a pentamethylphenyl group, an ethylphenyl group, a n-propylphenyl group, an isopropylphenyl group, a n-butylphenyl group, a sec-butylphenyl group, a tert-butylphenyl group, an isobutylphenyl group, a n-pentylphenyl group, a neopentylphenyl group, a n-hexylphenyl group, a n-octylphenyl group, a n-decylphenyl group, a n-dodecylphenyl group, a n-tetradecylphenyl group, a naphthyl group and an anthracenyl group.

The aryl group is preferably an aryl group having 6 to 20 carbon atoms, and more preferably a phenyl group or a 2-, 3-, or 4-tolyl group.

Examples of the aralkyl group as  $L^1$  are a benzyl group, a (2-methylphenyl)methyl group, a (3-methylphenyl)methyl group, a (4-methylphenyl)methyl group, a (2,3-dimethylphenyl)methyl group, a (2,4-dimethylphenyl)methyl group, a (2,5-dimethylphenyl)methyl group, a (2,6-dimethylphenyl)methyl group, a (3,4-dimethylphenyl)methyl group, a (3,5-dimethylphenyl)methyl group, a

(2,3,4-trimethylphenyl)methyl group, a  
 (2,3,5-trimethylphenyl)methyl group, a  
 (2,3,6-trimethylphenyl)methyl group, a  
 (3,4,5-trimethylphenyl)methyl group, a  
 5 (2,4,6-trimethylphenyl)methyl group, a  
 (2,3,4,5-tetramethylphenyl)methyl group, a  
 (2,3,4,6-tetramethylphenyl)methyl group, a  
 (2,3,5,6-tetramethylphenyl)methyl group, a  
 (pentamethylphenyl)methyl group, an (ethylphenyl)methyl  
 10 group, a (n-propylphenyl)methyl group, an  
 (isopropylphenyl)methyl group, a (n-butylphenyl)methyl group,  
 a (sec-butylphenyl)methyl group, a (tert-butylphenyl)methyl  
 group, a (n-pentylphenyl)methyl group, a  
 (neopentylphenyl)methyl group, a (n-hexylphenyl)methyl group,  
 15 a (n-octylphenyl)methyl group, a (n-decylphenyl)methyl group,  
 a (tetradecylphenyl)methyl group, a naphthylmethyl group and  
 an anthracenylmethyl group.

The aralkyl group as  $L^1$  is preferably an aralkyl group  
 having 7 to 20 carbon atoms, and more preferably a benzyl group.

20 Examples of the alkoxy group as  $L^1$  are a methoxy group,  
 an ethoxy group, a n-propoxy group, an isopropoxy group, a  
 n-butoxy group, a sec-butoxy group, a tert-butoxy group, an  
 isobutoxy group, a n-pentyloxy group, a neopentyloxy group,  
 a tert-pentyloxy group, a n-hexyloxy group, a n-heptyloxy group,  
 25 a n-octyloxy group, a n-decyloxy group, a n-dodecyloxy group,  
 a n-pentadecyloxy group and a n-eicosyl oxy group.

The alkoxy group as  $L^1$  is preferably an alkoxy group having  
 1 to 20 carbon atoms, and more preferably a methoxy group,  
 an ethoxy group, an isopropoxy group, a tert-butoxy group,  
 30 an isobutoxy group, a neopentoxyl group or a tert-pentyloxy

group.

Specific examples of the aryloxy group as L<sup>1</sup> are a phenoxy group, a 2-tolyloxy group, a 3-tolyloxy group, a 4-tolyloxy group, a 2,3-xylyloxy group, a 2,4-xylylphenoxy group, a 2,5-xylyloxy group, a 2,6-xylyloxy group, a 3,4-xylyloxy group, a 3,5-xylyloxy group, a 2,3,4-trimethylphenoxy group, a 2,3,5-trimethylphenoxy group, a 2,3,6-trimethylphenoxy group, a 2,4,6-trimethylphenoxy group, a 3,4,5-trimethylphenoxy group, a 2,3,4,5-tetramethylphenoxy group, a 2,3,4,6-tetramethylphenoxy group, a 2,3,5,6-tetramethylphenoxy group, a pentamethylphenoxy group, an ethylphenoxy group, a n-propylphenoxy group, an isopropylphenoxy group, a n-butylphenoxy group, a sec-butylphenoxy group, a tert-butylphenoxy group, an isobutylphenoxy group, a n-pentylphenoxy group, a neopentylphenoxy group, a n-hexylphenoxy group, a n-octylphenoxy group, a n-decylphenoxy group, a n-tetradecylphenoxy group, a naphthoxy group and an anthrathenoxy group.

The aryloxy group is preferably an aryloxy group having 6 to 20 carbon atoms, and more preferably a phenoxy group.

These alkyl, aryl, aralkyl, alkoxy and aryloxy groups above-mentioned as L<sup>1</sup> may be respectively substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.



As  $L^1$  in the above formula [1], preferred is a halogen atom, an alkyl group, an aryl group, an alkoxy group or an aryloxy group, more preferred is a halogen atom, an alkyl group, an aryl group, an alkoxy group or an aryloxy group, and particularly preferable is an alkyl group or an aryl group.

Examples of the compound (a) represented by the formula [1], wherein  $M^1$  is a bismuth atom, are a halogenated bismuth (III) such as bismuth (III) fluoride, bismuth (III) chloride, bismuth (III) bromide and bismuth (III) iodide; a trialkyl bismuth such as trimethyl bismuth; a triaryl bismuth such as triphenyl bismuth; a trialkoxy bismuth such as trimethoxy bismuth, triethoxy bismuth, triisopropoxy bismuth, tri(tert-butoxy) bismuth, triisobutoxy bismuth, trineopentyloxy bismuth and tri(tert-pentyloxy) bismuth; a triaryloxy bismuth such as triphenoxy bismuth, tri(2-tolyloxy) bismuth, tri(3-tolyloxy) bismuth, tri(4-tolyloxy) bismuth, tri(2,3-xylyloxy) bismuth, tri(2,4-xylyloxy) bismuth, tri(2,5-xylyloxy) bismuth, tri(2,6-xylyloxy) bismuth, tri(3,4-xylyloxy) bismuth, tri(3,5-xylyloxy) bismuth, tri(2,3,4-trimethylphenoxy) bismuth, tri(2,3,5-trimethylphenoxy) bismuth, tri(2,3,6-trimethylphenoxy) bismuth, tri(2,4,6-trimethylphenoxy) bismuth, tri(3,4,5-trimethylphenoxy) bismuth, tri(2,3,4,5-tetramethylphenoxy) bismuth, tri(2,3,4,6-tetramethylphenoxy) bismuth, tri(2,3,5,6-tetramethylphenoxy) bismuth, tri(pentamethylphenoxy) bismuth, tri(ethylphenoxy) bismuth, tri(n-propylphenoxy) bismuth, tri(isopropylphenoxy) bismuth, tri(n-butylphenoxy) bismuth, tri(sec-butylphenoxy) bismuth,

tri(tert-butylphenoxy) bismuth, tri(isobutylphenoxy) bismuth,  
 tri(n-pentylphenoxy) bismuth, tri(neopentylphenoxy) bismuth,  
 tri(n-hexylphenoxy) bismuth, tri(n-octylphenoxy) bismuth,  
 tri(n-decylphenoxy) bismuth, tri(n-dodecylphenoxy) bismuth,  
 5 tri(n-tetradecylethylphenoxy) bismuth, trinaphtyloxy bismuth  
 and trianthracenyloxy bismuth; a halogenated bismuth(V) such  
 as bismuth(V)fluoride, bismuth(V)chloride, bismuth(V)bromide  
 and bismuth(V)iodide; a pentaalkyl bismuth such as pentamethyl  
 bismuth; a pentaalkoxy bismuths such as pentamethoxy bismuth  
 10 and pentaethoxy bismuth; and a pentaaryloxy bismuths such as  
 pentaphenoxy bismuth.

Examples of the compound (a) represented by the formula  
 [1], wherein  $M^1$  is an aluminum atom, are a trialkylaluminum  
 such as trimethylaluminum, triethylaluminum,  
 15 tripropylaluminum, tri-n-butylaluminum, triisobutylaluminum,  
 tri-n-hexyl aluminum and tri-n-octylaluminum; a  
 triarylaluminum such as triphenylaluminum,  
 trinaphthylaluminum and tri(pentafluorophenyl)aluminum; a  
 trialkenylaluminum such as triallylaluminum;  
 20 tri(cyclopentadienyl)aluminum; and a halogenated aluminum  
 such as a halogenated dialkylaluminum, for example,  
 dimethylaluminum chloride, diethylaluminum chloride,  
 dipropylaluminum chloride, di-n-butylaluminum chloride,  
 diisobutylaluminum chloride, di-n-hexylaluminum chloride,  
 25 dimethylaluminum bromide, diethylaluminum bromide,  
 dipropylaluminum bromide, di-n-butylaluminum bromide,  
 diisobutylaluminum bromide, di-n-hexylaluminum bromide,  
 dimethylaluminum iodide, diethylaluminum iodide,  
 dipropylaluminum iodide, di-n-butylaluminum iodide,  
 30 diisobutylaluminum iodide and di-n-hexylaluminum iodide.

Among these, the compound (a) is preferably a halogenated bismuth (III), a trialkyl bismuth, a triaryl bismuth, a trialkoxy bismuth, a triaryloxy bismuth or a trialkylaluminum; more preferably a halogenated bismuth (III), a triaryl bismuth, a trialkoxy bismuth, a triaryloxy bismuth or a trialkylaluminum such as trimethylaluminum, triethylaluminum, tripropylaluminum, tri-n-butylaluminum, triisobutylaluminum, tri-n-hexyl aluminum and tri-n-octylaluminum; and particularly preferably a triaryl bismuth such as triphenyl bismuth, or a trialkylaluminum such as trimethylaluminum, triethylaluminum, triisobutylaluminum and tri-n-octylaluminum.

Examples of the non-metal atom of T of the Group 15 are a nitrogen atom and a phosphorous atom, and examples of the non-metal atom of T of the Group 16 are an oxygen atom and a sulfur atom. T is preferably a nitrogen atom or an oxygen atom, and particularly preferably an oxygen atom.

In the above formula [2], when T is a non-metal atom of the Group 15, s is 3, and when T is a non-metal atom of the Group 16, s is 2.

In the formula [2], as an index of the electron-withdrawing property, the substituent constant  $\sigma$  of the Hammett's rule is known, and a functional group, in which the substituent constant  $\sigma$  of the Hammett's rule is positive, can be mentioned as an electron-withdrawing group.

Examples of the electron-withdrawing group are a fluorine atom, a chlorine atom, a bromine atom, an iodine atom, a cyano group, a nitro group, a carbonyl group, a sulfonyl group, and a phenyl group. Examples of a group containing an

electron-withdrawing group are a halogenated hydrocarbon group such as a halogenated alkyl group and a halogenated aryl group; a cyanated hydrocarbon group such as a cyanated aryl group; a nitrated hydrocarbon group such as a nitrated aryl groups; a hydrocarbonoxy carbonyl group such as an alkoxycarbonyl group, an aralkyloxycarbonyl group and an aryloxycarbonyl group; and an acyloxy group.

Examples of the halogenated alkyl group as  $R^1$  are a fluoromethyl group, a chloromethyl group, a bromomethyl group, an iodomethyl group, a difluoromethyl group, a dichloromethyl group, a dibromomethyl group, a diiodomethyl group, a trifluoromethyl group, a trichloromethyl group, a tribromomethyl group, a triiodomethyl group, a 2,2,2-trifluoroethyl group, a 2,2,2-trichloroethyl group, a 2,2,2-tribromoethyl group, a 2,2,2-triiodoethyl group, a 2,2,3,3,3-pentafluoropropyl group, a 2,2,3,3,3-pentachloropropyl group, a 2,2,3,3,3-pentabromopropyl group, a 2,2,3,3,3-pentaiodopropyl group, a 2,2,2-trifluoro-1-trifluoromethylethyl group, a 2,2,2-trichloro-1-trichloromethylethyl group, a 2,2,2-tribromo-1-tribromomethylethyl group, a 2,2,2-triiodo-1-triiodomethylethyl group, a bis(trifluoromethyl)methyl group, a bis(trichloromethyl)methyl group, a bis(tribromomethyl)methyl group, a bis(triiodomethyl)methyl group, a 1,1-bis(trifluoromethyl)-2,2,2-trifluoroethyl group, a 1,1-bis(trichloromethyl)-2,2,2-trichloroethyl group, a 1,1-bis(tribromomethyl)-2,2,2-tribromoethyl group, and a 1,1-bis(triiodomethyl)-2,2,2-triiodoethyl group.

Examples of the halogenated aryl group as  $R^1$  are aryl groups in which a hydrogen atom of an aromatic ring in the group is substituted with a halogen such as a 2-fluorophenyl group, a 3-fluorophenyl group, a 4-fluorophenyl group, a 2-chlorophenyl group, a 3-chlorophenyl group, a 4-chlorophenyl group, a 2-bromophenyl group, a 3-bromophenyl group, a 4-bromophenyl group, a 2-iodophenyl group, a 3-iodophenyl group, a 4-iodophenyl group, a 2,6-difluorophenyl group, a 3,5-difluorophenyl group, a 3,4,5-trifluorophenyl group, a 2,6-dichlorophenyl group, a 3,5-dichlorophenyl group, a 2,6-dibromophenyl group, a 3,5-dibromophenyl group, a 2,6-diiodophenyl group, a 3,5-diiodophenyl group, a 2,4,6-trifluorophenyl group, a 2,4,6-trichlorophenyl group, a 2,4,6-tribromophenyl group, a 2,4,6-triiodophenyl group, a pentafluorophenyl group, a pentachlorophenyl group, a pentabromophenyl group, and a pentaiodophenyl group.

Further, examples of the (halogenated alkyl)aryl group as  $R^1$  are aryl groups substituted with a halogenated alkyl group such as a 2-(trifluoromethyl)phenyl group, a 3-(trifluoromethyl)phenyl group, a 4-(trifluoromethyl)phenyl group, a 2,6-bis(trifluoromethyl)phenyl group, a 3,5-bis(trifluoromethyl)phenyl group, and a 2,4,6-tris(trifluoromethyl)phenyl group.

Examples of the cyanated aryl group as  $R^1$  are a 2-cyanophenyl group, a 3-cyanophenyl group and a 4-cyanophenyl group.

Examples of the nitrated aryl group as  $R^1$  are a 2-nitrophenyl group, a 3-nitrophenyl group and a 4-nitrophenyl group.

Examples of the alkoxycarbonyl group as  $R^1$  are a

methoxycarbonyl group, an ethoxycarbonyl group, a  
n-propoxycarbonyl group, an isopropoxycarbonyl group and a  
trifluoromethoxycarbonyl group.

An example of the aralkyloxycarbonyl group as  $R^1$  is a  
benzyloxycarbonyl group.

Examples of the aryloxycarbonyl group as  $R^1$  are a  
phenoxycarbonyl group and a pentafluorophenoxycarbonyl group.

Examples of the acyloxycarbonyl group as  $R^1$  are a  
methycarbonyloxy group and an ethylcarbonyloxy group.

$R^1$  is preferably a halogenated hydrocarbon group; more  
preferably a halogenated alkyl group or a halogenated aryl  
group; further preferably a fluoroalkyl group, a fluoroaryl  
group, a chloroalkyl group or a chloroaryl group; furthermore  
preferably a fluoroalkyl group or a fluoroaryl group;  
particularly preferably a fluoromethyl group, a difluoromethyl  
group, a trifluoromethyl group, a 2,2,2-trifluoroethyl group,  
a 2,2,3,3,3-pentafluoropropyl group, a  
2,2,2-trifluoro-1-trifluoromethylethyl group, a  
bis(trifluoromethyl)methyl group, a  
1,1-bis(trifluoromethyl)-2,2,2-trifluoroethyl group, a  
4-fluorophenyl group, a 2,6-difluorophenyl group, a  
3,5-difluorophenyl group, a 2,4,6-trifluorophenyl group, a  
3,4,5-trifluorophenyl group or a pentafluorophenyl group; and  
most preferably a trifluoromethyl group, a  
2,2,2-trifluoro-1-trifluoromethylethyl group, a  
bis(trifluoromethyl)methyl group, a  
1,1-bis(trifluoromethyl)-2,2,2-trifluoroethyl group, a  
3,4,5-trifluorophenyl group, or a pentafluorophenyl group.

When the compound (b) represented by the above formula  
[2] is an amine, examples thereof are di(fluoromethyl)amine,

di(chloromethyl)amine, di(bromomethyl)amine,  
 di(iodomethyl)amine, bis(difluoromethyl)amine,  
 bis(dichloromethyl)amine, bis(dibromomethyl)amine,  
 bis(diiodomethyl)amine, bis(trifluoromethyl)amine,  
 5 bis(trichloromethyl)amine, bis(tribromomethyl)amine,  
 bis(triiodomethyl)amine, bis (2,2,2-trifluoroethyl) amine,  
 bis(2,2,2- trichloroethyl)amine,  
 bis(2,2,2-tribromoethyl)amine,  
 bis(2,2,2-triiodoethyl)amine,  
 10 bis(2,2,3,3,3-pentafluoropropyl)amine,  
 bis(2,2,3,3,3-pentachloropropyl)amine,  
 bis(2,2,3,3,3-pentabromopropyl)amine,  
 bis(2,2,3,3,3-pentaiodopropyl)amine,  
 bis(2,2,2-trifluoro-1-trifluoromethylethyl)amine,  
 15 bis(2,2,2-trichloro-1-trichloromethylethyl)amine,  
 bis(2,2,2-tribromo-1-tribromomethylethyl)amine,  
 bis(2,2,2-triiodo-1-triiodomethylethyl)amine,  
 bis(1,1-bis(trifluoromethyl)-2,2,2-trifluoroethyl)amine,  
 bis(1,1-bis(trichloromethyl)-2,2,2-trichloroethyl)amine,  
 20 bis(1,1-bis(tribromomethyl)-2,2,2-tribromoethyl)amine,  
 bis(1,1-bis(triiodomethyl)-2,2,2-triiodoethyl)amine,  
 bis(2-fluorophenyl)amine, bis(3-fluorophenyl)amine,  
 bis(4-fluorophenyl)amine, bis(2-chlorophenyl)amine,  
 bis(3-chlorophenyl)amine, bis(4-chlorophenyl)amine,  
 25 bis(2-bromophenyl)amine, bis(3-bromophenyl)amine,  
 bis(4-bromophenyl)amine, bis(2-iodophenyl)amine,  
 bis(3-iodophenyl)amine, bis(4-iodophenyl)amine,  
 bis(2,6-difluorophenyl)amine, bis(3,5-difluorophenyl)amine,  
 bis(2,6-dichlorophenyl)amine, bis(3,5-dichlorophenyl)amine,  
 30 bis(2,6-dibromophenyl)amine, bis(3,5-dibromophenyl)amine,

bis(2,6-diiodophenyl)amine, bis(3,5-diiodophenyl)amine,  
 bis(2,4,6-trifluorophenyl)amine,  
 bis(2,4,6-trichlorophenyl)amine,  
 bis(2,4,6-tribromophenyl)amine,  
 5 bis(2,4,6-triiodophenyl)amine, bis(pentafluorophenyl)amine,  
 bis(pentachlorophenyl)amine, bis(pentabromophenyl)amine,  
 bis(pentaiodophenyl)amine,  
 bis(2-(trifluoromethyl)phenyl)amine,  
 bis(3-(trifluoromethyl)phenyl)amine,  
 10 bis(4-(trifluoromethyl)phenyl)amine,  
 bis(2,6-di(trifluoromethyl)phenyl)amine,  
 bis(3,5-di(trifluoromethyl)phenyl)amine,  
 bis(2,4,6-tri(trifluoromethyl)phenyl)amine,  
 bis(2-cyanophenyl)amine, bis(3-cyanophenyl)amine,  
 15 bis(4-cyanophenyl)amine, bis(2-nitrophenyl)amine,  
 bis(3-nitrophenyl)amine and bis(4-nitrophenyl)amine.

When the compound (b) is a phosphine, examples thereof  
 are phosphine compounds in which a nitrogen atom is replaced  
 with a phosphorus atom in the above-mentioned amine compounds.

20 When the compound (b) represented by the above formula  
 [2] is an alcohol, examples thereof are fluoromethanol,  
 chloromethanol, bromomethanol, iodomethanol,  
 difluoromethanol, dichloromethanol, dibromomethanol,  
 diiodomethanol, trifluoromethanol, trichloromethanol,  
 25 tribromomethanol, triiodomethanol, 2,2,2-trifluoroethanol,  
 2,2,2-trichloroethanol, 2,2,2-tribromoethanol,  
 2,2,2-triiodoethanol, 1,1,1,3,3,3-hexafluoro-2-propanol,  
 1,1,1,3,3,3-hexachloro-2-propanol,  
 1,1,1,3,3,3-hexabromo-2-propanol,  
 30 1,1,1,3,3,3-hexaiodo-2-propanol,



1,1,1,3,3,3-hexafluoro-2-(trifluoromethyl)-2-propanol,  
 1,1,1,3,3,3-hexachloro-2-(trifluoromethyl)-2-propanol,  
 1,1,1,3,3,3-hexabromo-2-(trifluoromethyl)-2-propanol,  
 1,1,1,3,3,3-hexaiodo-2-(trifluoromethyl)-2-propanol,  
 5 1H,1H,3H-perfluoropropanol, 1H,1H,3H-perchloropropanol,  
 1H,1H,3H-perbromopropanol, 1H,1H,3H-periodopropanol,  
 1H,1H-perfluoropropanol, 1H,1H-perchloropropanol,  
 1H,1H-perbromopropanol, 1H,1H-periodopropanol,  
 1H,1H,4H-perfluorobutanol, 1H,1H,4H-perchlorobutanol,  
 10 1H,1H,4H-perbromobutanol, 1H,1H,4H-periodobutanol,  
 1H,1H-perfluorobutanol, 1H,1H-perchlorobutanol,  
 1H,1H-perbromobutanol, 1H,1H-periodobutanol,  
 1H,1H,5H-perfluoropentanol, 1H,1H,5H-perchloropentanol,  
 1H,1H,5H-perbromopentanol, 1H,1H,5H-periodopentanol,  
 15 1H,1H-perfluoropentanol, 1H,1H-perchloropentanol,  
 1H,1H-perbromopentanol, 1H,1H-periodopentanol,  
 1H,1H,6H-perfluorohexanol, 1H,1H,6H-perchlorohexanol,  
 1H,1H,6H-perbromohexanol, 1H,1H,6H-periodohexanol,  
 1H,1H-perfluorohexanol, 1H,1H-perchlorohexanol,  
 20 1H,1H-perbromohexanol, 1H,1H-periodohexanol,  
 1H,1H,8H-perfluorooctanol, 1H,1H,8H-perchlorooctanol,  
 1H,1H,8H-perbromooctanol, 1H,1H,8H-periodooctanol,  
 1H,1H-perfluorooctanol, 1H,1H-perchlorooctanol,  
 1H,1H-perbromooctanol and 1H,1H-periodooctanol.

25 When the compound (b) is a thiol compound, examples  
 thereof are thiol compounds in which an oxygen atom is replaced  
 with a sulfur atom in the above-mentioned alcohol compounds.

When the compound (b) is a phenol, examples thereof are  
 2-fluorophenol, 3-fluorophenol, 4-fluorophenol,  
 30 2-chlorophenol, 3-chlorophenol, 4-chlorophenol,

2-bromophenol, 3-bromophenol, 4-bromophenol, 2-iodophenol,  
 3-iodophenol, 4-iodophenol, 2,6-difluorophenol,  
 3,5-difluorophenol, 2,6-dichlorophenol, 3,5-dichlorophenol,  
 2,6-dibromophenol, 3,5-dibromophenol, 2,6-diiodophenol,  
 5 3,5-diiodophenol, 2,4,6-trifluorophenol,  
 3,4,5-trifluorophenol, 2,4,6-trichlorophenol,  
 2,4,6-tribromophenol, 2,4,6-triiodophenol,  
 pentafluorophenol, pentachlorophenol, pentabromophenol,  
 pentaiodophenol, 2-(trifluoromethyl)phenol,  
 10 3-(trifluoromethyl)phenol, 4-(trifluoromethyl)phenol,  
 2,6-bis(trifluoromethyl)phenol,  
 3,5-bis(trifluoromethyl)phenol, 2-cyanophenol,  
 3-cyanophenol, 4-cyanophenol, 2-nitrophenol, 3-nitrophenol  
 and 4-nitrophenol.

15           When the compound (b) is a thiophenol compound, examples  
 thereof are thiophenol compounds in which an oxygen atom is  
 replaced with a sulfur atom in the above-mentioned phenol  
 compounds.

          When the compounds (b) is a carboxylic acid, examples  
 20 thereof are 2-fluorobenzoic acid, 3-fluorobenzoic acid,  
 4-fluorobenzoic acid, 2,3-difluorobenzoic acid,  
 2,4-difluorobenzoic acid, 2,5-difluorobenzoic acid,  
 2,6-difluorobenzoic acid, 2,3,4-trifluorobenzoic acid,  
 2,3,5-trifluorobenzoic acid, 2,3,6-trifluorobenzoic acid,  
 25 2,4,5-trifluorobenzoic acid, 2,4,6-trifluorobenzoic acid,  
 2,3,4,5-tetrafluorobenzoic acid, 2,3,4,6-tetrafluorobenzoic  
 acid, pentafluorobenzoic acid, fluoroacetic acid,  
 difluoroacetic acid, trifluoroacetic acid,  
 pentafluoropropanoic acid, heptafluorobutanoic acid and  
 30 1,1-bis(trifluoromethyl)-2,2,2-trifluoroethanoic acid.

When the compounds (b) is a sulfonic acid, examples thereof are fluoromethanesulfonic acid, difluoromethanesulfonic acid, trifluoromethanesulfonic acid, pentafluoroethanesulfonic acid, heptafluoropropanesulfonic acid, and 1,1-bis(trifluoromethyl)-2,2,2-trifluoroethane sulfonic acid.

A preferable amine of the compound (b) is bis(trifluoromethyl)amine, bis(2,2,2-trifluoromethyl)amine, bis(2,2,3,3,3-pentafluoropropyl)amine, bis(2,2,2-trifluoro-1-trifluoromethylethyl)amine, bis(1,1-bis(trifluoromethyl)-2,2,2-trifluoroethyl)amine or bis(pentafluorophenyl)amine; preferable alcohols thereof are trifluoromethanol, 2,2,2-trifluoroethanol, 2,2,3,3,3-pentafluoropropanol, 1,1,1,3,3,3-hexafluoro-2-propanol, 2,2,2-trifluoro-1-trifluoromethylethanol or 1,1-bis(trifluoromethyl)-2,2,2-trifluoroethanol; a preferable phenol thereof is 2-fluorophenol, 3-fluorophenol, 4-fluorophenol, 2,6-difluorophenol, 3,5-difluorophenol, 2,4,6-trifluorophenol, 3,4,5-trifluorophenol, pentafluorophenol, 2-(trifluoromethyl)phenol, 3-(trifluoromethyl)phenol, 4-(trifluoromethyl)phenol, 2,6-bis(trifluoromethyl)phenol, 3,5-bis(trifluoromethyl)phenol or 2,4,6-tris(trifluoromethyl)phenol; a preferable carboxylic acid thereof is pentafluorobenzoic acid or trifluoroacetic acid; and a preferable sulfonic acid thereof is trifluoromethanesulfonic acid.

A more preferable compound (b) is

bis(trifluoromethyl)amine, bis(pentafluorophenyl) amine,  
 trifluoromethanol, 1,1,1,3,3,3-hexafluoro-2-propanol,  
 1,1,1,3,3,3-hexafluoro-2-(trifluoromethyl)-2-propanol,  
 4-fluorophenol, 2,6-difluorophenol, 2,4,6-trifluorophenol,  
 5 3,4,5-trifluorophenol, pentafluorophenol,  
 4-(trifluoromethyl)phenol, 2,6-bis(trifluoromethyl)phenol  
 or 2,4,6-tris(trifluoromethyl)phenol; and a further  
 preferable compound (b) is 3,4,5-trifluorophenol,  
 pentafluorophenol, 1,1,1,3,3,3-hexafluoro-2-propanol or  
 10 1,1,1,3,3,3-hexafluoro-2-(trifluoromethyl)-2-propanol.

Examples of J in the above-mentioned formula [3] are  
 a carbon atom and a silicon atom. Among them, a silicon atom  
 is preferable. In the above-mentioned formula [3], n is the  
 number of from 2 to 4, preferably 2 or 3, and more preferably  
 15 2.

Examples of the hydrocarbon group as  $R^2$  are hydrocarbon  
 groups as  $L^1$ , and halogenated hydrocarbon groups as  $R^1$  mentioned  
 above, respectively.  $R^2$  is preferably an alkyl group or an aryl  
 group, more preferably an aryl group, and further preferably  
 20 a phenyl group.

Examples of the compound (c) represented by the formula  
 [3] are dimethylsilanediol, diethylsilanediol,  
 di(n-propyl)silanediol, diisopropylsilanediol,  
 di(n-butyl)silanediol, di(sec-butyl)silanediol,  
 25 di(tert-butyl)silanediol, diisobutylsilanediol,  
 di(n-pentyl)silanediol, dineopentylsilanediol,  
 di(n-hexyl)silanediol, di(n-heptyl)silanediol,  
 di(n-octyl)silanediol, di(n-decyl)silanediol,  
 di(n-dodecyl)silanediol, di(n-pentadecyl)silanediol,

di(n-eicosyl)silanediol, diphenylsilanediol,  
 di(2-tolyl)silanediol, di(3-tolyl)silanediol,  
 di(4-tolyl)silanediol, di(2,3-xylyl)silanediol,  
 di(2,4-xylyl)silanediol, di(2,5-xylyl)silanediol,  
 5 di(2,6-xylyl)silanediol, di(3,4-xylyl)silanediol,  
 di(3,5-xylyl)silanediol,  
 di(2,3,4-trimethylphenyl)silanediol,  
 di(2,3,5-trimethylphenyl)silanediol,  
 di(2,3,6-trimethylphenyl)silanediol,  
 10 di(2,4,6-trimethylphenyl)silanediol,  
 di(3,4,5-trimethylphenyl)silanediol,  
 di(2,3,4,5-tetramethylphenyl)silanediol,  
 di(2,3,4,6-tetramethylphenyl)silanediol,  
 di(2,3,5,6-tetramethylphenyl)silanediol,  
 15 di(pentamethylphenyl)silanediol, di(ethylphenyl)silanediol,  
 di(n-propylphenyl)silanediol,  
 di(isopropylphenyl)silanediol, di(n-butylphenyl)silanediol,  
 di(sec-butylphenyl)silanediol,  
 di(tert-butylphenyl)silanediol,  
 20 di(isobutylphenyl)silanediol, di(n-pentylphenyl)silanediol,  
 di(neopentylphenyl)silanediol, di(n-hexylphenyl)silanediol,  
 di(n-octylphenyl)silanediol, di(n-decylphenyl)silanediol,  
 di(n-dodecylphenyl)silanediol,  
 di(n-tetradecylphenyl)silanediol, dinaphthylsilanediol,  
 25 dianthracenylsilanediol,  
 di(pentafluorophenyl)silanediol, methylsilanetriol,  
 ethylsilanetriol, n-propylsilanetriol, isopropylsilanetriol,  
 n-butylsilanetriol, sec-butylsilanetriol,

tert-butylsilanetriol, isobutylsilanetriol,  
 n-pentylsilanetriol, neopentylsilanetriol,  
 n-hexylsilanetriol, n-heptylsilanetriol, n-octylsilanetriol,  
 n-decylsilanetriol, n-dodecylsilanetriol,  
 5 n-pentadecylsilanetriol, n-eicosylsilanetriol,  
 phenylsilanetriol, 2-tolylsilanetriol, 3-tolylsilanetriol,  
 4-tolylsilanetriol, 2,3-xylylsilanetriol,  
 2,4-xylylsilanetriol, 2,5-xylylsilanetriol,  
 2,6-xylylsilanetriol, 3,4-xylylsilanetriol,  
 10 3,5-xylylsilanetriol, 2,3,4-trimethylphenylsilanetriol,  
 2,3,5-trimethylphenylsilanetriol,  
 2,3,6-trimethylphenylsilanetriol,  
 2,4,6-trimethylphenylsilanetriol,  
 3,4,5-trimethylphenylsilanetriol,  
 15 2,3,4,5-tetramethylphenylsilanetriol,  
 2,3,4,6-tetramethylphenylsilanetriol,  
 2,3,5,6-tetramethylphenylsilanetriol,  
 pentamethylphenylsilanetriol, ethylphenylsilanetriol,  
 n-propylphenylsilanetriol, isopropylphenylsilanetriol,  
 20 n-butylphenylsilanetriol, sec-butylphenylsilanetriol,  
 tert-butylphenylsilanetriol, isobutylphenylsilanetriol,  
 n-pentylphenylsilanetriol, neopentylphenylsilanetriol,  
 n-hexylphenylsilanetriol, n-octylphenylsilanetriol,  
 n-decylphenylsilanetriol, n-dodecylphenylsilanetriol,  
 25 n-tetradecylphenylsilanetriol, naphthylsilanetriol,  
 anthracenylsilanetriol, pentafluorophenylsilanetriol and  
 tetrahydroxysilane.

The compound (c) is preferably

dimethylsilanediol, diethylsilanediol,  
 diisopropylsilanediol, di(tert-butyl)silanediol,  
 diphenylsilanediol, di(2-tolyl)silanediol,  
 di(3-tolyl)silanediol, di(4-tolyl)silanediol,  
 5 di(2,4,6-trimethylphenyl)silanediol, tetrahydroxysilane,  
 pentafluorophenylsilanetriol or  
 di(pentafluorophenyl)silanediol; and most preferably  
 diphenylsilanediol.

A method for contacting the compounds (a) to (c) is not  
 10 particularly limited. Examples thereof are as follows.

① A method of contacting (c) after contacting (a) and  
 (b).

② A method of contacting (b) after contacting (a) and  
 (c).

15 ③ A method of contacting (a) after contacting (b) and  
 (c).

Preferred is ① or ②. Namely, the metal compound  
 according to the present invention is preferably obtained by  
 contacting (c) with a contact product obtained by contacting  
 20 (a) and (b), or by contacting (b) with a contact product obtained  
 by contacting (a) and (c). Further, there may be carried out  
 either a method comprising the steps of:

(1) contacting (a) and (b), (a) and (c), or (b) and (c)  
 to obtain a contact product, and

25 (2) contacting the contact product with the remaining  
 compound,

or a method comprising the steps of:

(1) contacting (a) and (b), (a) and (c), or (b) and (c)  
 to obtain a contact product,

(2) purifying the contact product to obtain a purified contact product, and

(3) contacting the purified contact product with the remaining compound.

5           The contact treatment of the above-mentioned compounds (a) to (c) is preferably carried out under an inert gas atmosphere. The treatment temperature is usually from  $-100$  to  $300^{\circ}\text{C}$ , preferably from  $-80$  to  $200^{\circ}\text{C}$ , and further preferably from  $0$  to  $150^{\circ}\text{C}$ . The treatment time is usually from 1 minute to 200  
10 hours, and preferably from 10 minutes to 100 hours. Further, a solvent may be used in the treatment, or these compounds may be directly contact-treated using no solvent. There can be used any solvent selected from a non-polar solvent such as an aliphatic hydrocarbon solvent and an aromatic hydrocarbon  
15 solvent, and a polar solvent such as a halogenated solvent and an etheral solvent, which is inert to the compounds (a) to (c). Examples of the solvent are butane, hexane, heptane, octane, 2,2,4-trimethylpentane, cyclohexane, benzene, toluene, xylene, dichloromethane, difluoromethane,  
20 chloroform, 1,2-dichloroethane, 1,2-dibromoethane, 1,1,2-trichloro-1,2,2-trifluoroethane, tetrachloroethylene, chlorobenzene, bromobenzene, o-dichlorobenzene, dimethyl ether, diethyl ether, diisopropyl ether, di-n-butyl ether, methyl tert-butyl ether, anisole, 1,4-dioxane,  
25 1,2-dimethoxyethane, bis(2-methoxyethyl) ether, tetrahydrofuran and tetrahydropyran.

Regarding the amounts of the respective compounds used in the preparation of the metal compound, when the molar ratio of the amounts of the respective compounds used is defined  
30 as a molar ratio of (a):(b):(c) =  $1:y:z$ ,  $y$  is from 0.1 to



8, preferably from 1 to 6, more preferably from 2 to 4, and further preferably from 2.5 to 3.5. The above Z is from 0.5 to 8, preferably from 0.6 to 6, more preferably from 0.7 to 4, and further preferably from 0.8 to 1.2.

5           As a result of the contact treatment, at least one of compounds (a) to (c), which are raw materials, may remain as an unreacted matter in the metal compound according to the present invention.

10           When the compounds (a) to (c) are triphenyl bismuth, pentafluorophenol and diphenylsilanediol, respectively, an example of a process for producing the metal compound according to the present invention comprises the steps of:

15           (1) adding dropwise a toluene solution containing pentafluorophenol in amount of three times by mole to triphenyl bismuth to a toluene solution of triphenyl bismuth,

            (2) stirring for from 10 minutes to 24 hours at room temperature,

            (3) stirring under a refluxing condition for from 10 minutes to 24 hours,

20           (4) concentrating the solution,

            (5) filtering a precipitated solid component,

            (6) drying the solid component,

            (7) adding toluene and diphenylsilanediol to the obtained solid component,

25           (8) stirring under a refluxing condition for from 10 minutes to 24 hours,

            (9) concentrating the solution,

            (10) filtering a precipitated solid component, and

            (11) drying the solid component,

30           The metal compound (hereinafter, referred to as

"compound (A)") according to the present invention can preferably be used as a catalyst component of a catalyst for addition polymerization. Examples of the catalyst for addition polymerization using said catalyst component are (1) a catalyst  
 5 obtained by a process comprising the step of contacting the compound (A) with the compound (B), and (2) a catalyst obtained by a process comprising the step of contacting the compound (A) with the compound (B) and the compound (C). In order to obtain a catalyst having a high polymerization activity, the  
 10 above latter catalyst is preferable.

Preferable examples of the compound (B) are a metal compound represented by the following formula [4], and a  $\mu$ -oxo type metal compound thereof:



wherein a is a number satisfying  $0 < a \leq 8$ ; b is a number satisfying  $0 < b \leq 8$ ;  $M^2$  is a metal atom of the Groups 3 to 11 or Lanthanide Series of the Periodic Table of the Elements;  
 20  $L^2$  is a group having a cyclopentadienyl type anion skeleton, or a group containing a hetero-atom, a plurality of  $L^2$  groups may be the same or different each other, and a plurality of  $L^2$  groups may be optionally linked in direct, or through a group containing a carbon atom, a silicon atom, a nitrogen atom,  
 25 an oxygen atom, a sulfur atom or a phosphorus atom;  $X^1$  is a halogen atom, a hydrocarbon group (excluding the group having a cyclopentadienyl type anion skeleton) or a hydrocarbonoxy group, and a plurality of  $X^1$  groups may be the same or different each other.

30 Examples of  $M^2$  are a scandium atom, an yttrium atom, a

titanium atom, a zirconium atom, a hafnium atom, a vanadium atom, a niobium atom, a tantalum atom, a chromium atom, an iron atom, a ruthenium atom, a cobalt atom, a rhodium atom, a nickel atom, a palladium atom, a samarium atom and an ytterbium atom.  $M^2$  is preferably a metal atom of Groups 3 to 11, and particularly preferably a titanium atom, a zirconium atom or a hafnium atom.

Examples of the group having a cyclopentadienyl type anion skeleton as  $L^2$  are an  $\eta^5$ -(substituted)cyclopentadienyl group, an  $\eta^5$ -(substituted)indenyl group, and an  $\eta^5$ -(substituted)fluorenyl group. Specific examples thereof are an  $\eta^5$ -cyclopentadienyl group, an  $\eta^5$ -methylcyclopentadienyl group, an  $\eta^5$ -tert-butylcyclopentadienyl group, an  $\eta^5$ -1,2-dimethylcyclopentadienyl group, an  $\eta^5$ -1,3-dimethylcyclopentadienyl group, an  $\eta^5$ -1-tert-butyl-2-methylcyclopentadienyl group, an  $\eta^5$ -1-tert-butyl-3-methylcyclopentadienyl group, an  $\eta^5$ -1-methyl-2-isopropylcyclopentadienyl group, an  $\eta^5$ -1-methyl-3-isopropylcyclopentadienyl group, an  $\eta^5$ -1,2,3-trimethylcyclopentadienyl group, an  $\eta^5$ -1,2,4-trimethylcyclopentadienyl group, an  $\eta^5$ -tetramethylcyclopentadienyl group, an  $\eta^5$ -pentamethylcyclopentadienyl group, an  $\eta^5$ -indenyl group, an  $\eta^5$ -4,5,6,7-tetrahydroindenyl group, an  $\eta^5$ -2-methylindenyl group, an  $\eta^5$ -3-methylindenyl group, an  $\eta^5$ -4-methylindenyl group, an  $\eta^5$ -5-methylindenyl group, an  $\eta^5$ -6-methylindenyl group, an  $\eta^5$ -7-methylindenyl group, an  $\eta^5$ -2-tert-butylindenyl group, an  $\eta^5$ -3-tert-butylindenyl group, an  $\eta^5$ -4-tert-butylindenyl group, an  $\eta^5$ -5-tert-butylindenyl group, an  $\eta^5$ -6-tert-butylindenyl group, an  $\eta^5$

<sup>5</sup>-7-tert-butylindenyl group, an  $\eta^5$ -2,3-dimethylindenyl group,  
 an  $\eta^5$ -4,7-dimethylindenyl group, an  $\eta$   
<sup>5</sup>-2,4,7-trimethylindenyl group, an  $\eta$   
<sup>5</sup>-2-methyl-4-isopropylindenyl group, an  $\eta^5$ -4,5-benzindenyl  
 5 group, an  $\eta^5$ -2-methyl-4,5-benzindenyl group, an  $\eta$   
<sup>5</sup>-4-phenylindenyl group, an  $\eta^5$ -2-methyl-5-phenylindenyl  
 group, an  $\eta^5$ -2-methyl-4-phenylindenyl group,  
 an  $\eta^5$ -2-methyl-4-naphthylindenyl group, an  $\eta^5$ -fluorenyl  
 group, an  $\eta^5$ -2,7-dimethylfluorenyl group and an  $\eta$   
 10 <sup>5</sup>-2,7-di-tert-butylfluorenyl group; and substitution groups  
 thereof.

Examples of the hetero-atom in the group containing a  
 hetero-atom as L<sup>2</sup> are an oxygen atom, a sulfur atom, a nitrogen  
 atom and a phosphorus atom. Examples of the group containing  
 15 a hetero-atom are an alkoxy group; an aryloxy group; a thioalkoxy  
 group; a thioaryloxy group; an alkylamino group; an arylamino  
 group; an alkylphosphino group; an arylphosphino group; an  
 aromatic or aliphatic heterocyclic group containing in its  
 ring at least one atom selected from the group consisting of  
 20 an oxygen atom, a sulfur atom, a nitrogen atom and a phosphorus  
 atom; and a chelating ligand.

Examples of the group containing a hetero-atom are  
 a methoxy group, an ethoxy group, a n- or iso-propoxy group,  
 a n-, sec-, iso- or tert-butoxy group, a phenoxy group, a  
 25 2-methylphenoxy group, a 2,6-dimethylphenoxy group, a  
 2,4,6-trimethylphenoxy group, a 2-ethylphenoxy group, a  
 4-n-propylphenoxy group, a 2-isopropylphenoxy group, a  
 2,6-diisopropylphenoxy group, a 4-sec-butylphenoxy group, a  
 4-tert-butylphenoxy group, a 2,6-di-sec-butylphenoxy group,  
 30 a 4-tert-butyl-4-methylphenoxy group, a

2,6-di-tert-butylphenoxy group, a 4-methoxyphenoxy group, a  
 2,6-dimethoxyphenoxy group, a 3,5-dimethoxyphenoxy group, a  
 2-chlorophenoxy group, a 4-nitrosophenoxy group, a  
 4-nitrophenoxy group, a 2-aminophenoxy group, a 3-aminophenoxy  
 5 group, a 4-aminothiophenoxy group, a 2,3,6-trichlorophenoxy  
 group, a 2,4,6-trifluorophenoxy group, a thiomethoxy group,  
 a dimethylamino group, a diethylamino group, a di-n- or  
 iso-propylamino group, a diphenylamino group, an  
 isopropylamino group, a tert-butylamino group, a pyrrolyl group,  
 10 a dimethylphosphino group, a 2-(2-oxy-1-propyl)phenoxy group,  
 a catecholato group, a 2-hydroxyphenoxy group, a resorcinolate  
 group, a 3-hydroxyphenoxy group, a 4-isopropyl-catecholato  
 group, a 2-hydroxy-4-isopropyl-phenoxy group, a  
 3-methoxycatecholato group, a 2-hydroxy-3-methoxyphenoxy  
 15 group, a 1,8-dihydroxynaphthyl group, a 1,2-dihydroxynaphthyl  
 group, a 2,2'-biphenyldiol group, a 1,1'-bi-2-naphthol group,  
 a 2,2'-dihydroxy-6,6'-dimethylbiphenyl group, a  
 4,4',6,6'-tetra-tert-butyl-2,2'-methylenediphenoxy group,  
 and a 4,4',6,6'-tetramethyl-2,2'-isobutylidenediphenoxy  
 20 group.

A further example of the hetero atom-containing group  
 is a group represented by the following formula [5]:

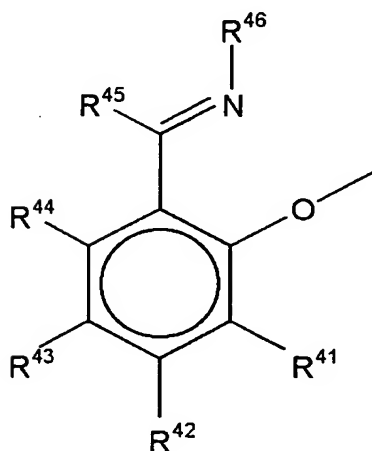


25 wherein  $R^3$  is a hydrogen atom, a halogen atom or a hydrocarbon  
 group, three  $R^3$  groups may be the same or different, and two  
 or more thereof may be bonded mutually, or may form a ring.

Examples of  $R^3$  in the formula [5] are a hydrogen atom,  
 30 a fluorine atom, a chlorine atom, a bromine atom, an iodine

atom, a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a tert-butyl group, a cyclohexyl group, a phenyl group, a 1-naphtyl group and a benzyl group.

5 A still further example of the hetero atom-containing group is a group represented by the following formula [6]:



[6]

10 wherein respective R<sup>41</sup> to R<sup>46</sup> groups are independently a hydrogen atom, a halogen atom, a hydrocarbon group, a hydrocarbon oxy group, a silyl group or an amino group, they may be the same or different, and two or more thereof may be bonded mutually, or may form a ring.

15 Examples of R<sup>41</sup> to R<sup>46</sup> in the above formula [6] are a hydrogen atom, a fluorine atom, a chlorine atom, a bromine atom, an iodine atom, a phenyl group, a 1-naphtyl group, a 2-naphtyl group, a tert-butyl group, a 2,6-dimethylphenyl group, a 2-fluorenyl group, a 2-methylphenyl group, a  
 20 4-trifluoromethylphenyl group, a 4-methoxyphenyl group, a 4-pyridyl group, a cyclohexyl group, a 2-isopropylphenyl group, a benzyl group, a methyl group, a triethylsilyl group, a diphenylmethylsilyl group, a 1-methy-1-phenylethyl group, a

1,1-dimethyl propyl group, a 2-chlorophenyl group and a pentafluorophenyl group.

The above-mentioned chelating ligand as  $L^2$  means a ligand having plural coordinating positions. Examples thereof are acetylacetonate, diimine, oxazoline, bisoxazoline, terpyridine, acylhydrazone, diethylenetriamine, triethylenetetramine, porphyrin, crown ether and cryptate.

Examples of the heterocyclic group as  $L^2$  are a pyridyl group, an N-substituted imidazolyl group and an N-substituted indazolyl group, and preferred is a pyridyl group.

Examples of the above-mentioned group, through which plural  $L^2$  groups are linked, are an alkylene group such as a methylene group, an ethylene group and a propylene group; a substituted alkylene group such as a dimethylmethylene group (an isopropylidene group) and a diphenylmethylene group; a silylene group; a substituted silylene group such as a dimethylsilylene group, a diethylsilylene group, a diphenylsilylene group, a tetramethyldisilylene group and a dimethoxysilylene group; and a hetero-atom such as a nitrogen atom, an oxygen atom, a sulfur atom and a phosphorus atom. Among them, particularly preferred is a methylene group, an ethylene group, a dimethylmethylene group (an isopropylidene group), a diphenylmethylene group, a dimethylsilylene group, a diethylsilylene group, a diphenylsilylene group or a dimethoxysilylene group.

Examples of the halogen atom as  $X^1$  are a fluorine atom, a chlorine atom, a bromine atom and an iodine atom. Examples of the hydrocarbon group as  $X^1$  are an alkyl group, an aralkyl group, an aryl group and an alkenyl group.

Examples of the alkyl group as  $X^8$  are a methyl group,

an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, a tert-butyl group, an isobutyl group, a n-pentyl group, a neopentyl group, an amyl group, a n-hexyl group, a n-octyl group, a n-decyl group, a n-dodecyl group, a  
 5 n-pentdecyl group and a n-eicosyl group.

Each of these alkyl groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom. Examples of such an alkyl group are a fluoromethyl group, a trifluoromethyl group, a chloromethyl  
 10 group, a trichloromethyl group, a fluoroethyl group, a pentafluoroethyl group, a perfluoropropyl group, a perfluorobutyl group, a perfluorohexyl group, a perfluorooctyl group, a perchloropropyl group, a perchlorobutyl group and a perbromopropyl group.

15 Further, these alkyl groups may be substituted with an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

The alkyl group as  $X^1$  is preferably an alkyl group having  
 20 1 to 20 carbon atoms, and more preferably a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, an isobutyl group or an amyl group.

Examples of the aralkyl group as  $X^1$  are a benzyl group, a (2-methylphenyl)methyl group, a (3-methylphenyl)methyl  
 25 group, a (4-methylphenyl)methyl group, a (2,3-dimethylphenyl)methyl group, a (2,4-dimethylphenyl)methyl group, a (2,5-dimethylphenyl)methyl group, a (2,6-dimethylphenyl)methyl group, a  
 30 (3,4-dimethylphenyl)methyl group, a



(3,5-dimethylphenyl)methyl group, a  
 (2,3,4-trimethylphenyl)methyl group, a  
 (2,3,5-trimethylphenyl)methyl group, a  
 (2,3,6-trimethylphenyl)methyl group, a  
 5 (3,4,5-trimethylphenyl)methyl group, a  
 (2,4,6-trimethylphenyl)methyl group, a  
 (2,3,4,5-tetramethylphenyl)methyl group, a  
 (2,3,4,6-tetramethylphenyl)methyl group, a  
 (2,3,5,6-tetramethylphenyl)methyl group, a  
 10 (pentamethylphenyl)methyl group, an (ethylphenyl)methyl  
 group, a (n-propylphenyl)methyl group, an  
 (isopropylphenyl)methyl group, a (n-butylphenyl)methyl group,  
 a (sec-butylphenyl)methyl group, a (tert-butylphenyl)methyl  
 group, a (n-pentylphenyl)methyl group, a  
 15 (neopentylphenyl)methyl group, a (n-hexylphenyl)methyl group,  
 a (n-octylphenyl)methyl group, a (n-decylphenyl)methyl group,  
 a (tetradecylphenyl)methyl group, a naphthylmethyl group and  
 an anthracenylmethyl group.

Each of these aralkyl groups may be substituted with  
 20 a halogen atom such as a fluorine atom, a chlorine atom, a  
 bromine atom and an iodine atom; an alkoxy group such as a  
 methoxy group and an ethoxy group; an aryloxy group such as  
 a phenoxy group; or an aralkyloxy group such as a benzyloxy  
 group.

25 The aralkyl group as  $X^1$  is preferably an aralkyl group  
 having 7 to 20 carbon atoms, and more preferably a benzyl group.

Examples of the aryl group as  $X^1$  are a phenyl group, a  
 2-tolyl group, a 3-tolyl group, a 4-tolyl group, a 2,3-xylyl  
 group, a 2,4-xylyl group, a 2,5-xylyl group, a 2,6-xylyl group,  
 30 a 3,4-xylyl group, a 3,5-xylyl group, a 2,3,4-trimethylphenyl

group, a 2,3,5-trimethylphenyl group, a 2,3,6-trimethylphenyl group, a 2,4,6-trimethylphenyl group, a 3,4,5-trimethylphenyl group, a 2,3,4,5-tetramethylphenyl group, a 2,3,4,6-tetramethylphenyl group, a 2,3,5,6-tetramethylphenyl group, a pentamethylphenyl group, an ethylphenyl group, a n-propylphenyl group, an isopropylphenyl group, a n-butylphenyl group, a sec-butylphenyl group, a tert-butylphenyl group, an isobutylphenyl group, a n-pentylphenyl group, a neopentylphenyl group, a n-hexylphenyl group, a n-octylphenyl group, a n-decylphenyl group, a n-dodecylphenyl group, a n-tetradecylphenyl group, a naphthyl group and an anthracenyl group.

Each of these aryl groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

The aryl group is preferably an aryl group having 6 to 20 carbon atoms, and more preferably a phenyl group.

Examples of the alkenyl group as  $X^1$  are an ally group, a methally group, a crotyl group and a 1,3-diphenyl-2-propenyl group. The alkenyl group is preferably an alkenyl group having 3 to 20 carbon atoms, and more preferably an ally group or a methally group.

Examples of the hydrocarbonoxy group as  $X^1$  are an alkoxy group, an aryloxy group and an aralkyloxy group. Preferred is an alkoxy group having 1 to 20 carbon atoms, an aryloxy group having 6 to 20 carbon atoms, or an aralkyloxy group having 7 to 20 carbon atoms. Examples thereof are hydrocarbonoxy groups as above-exemplified as  $L^1$ , a (2-methylphenyl)methoxy group,

a (3-methylphenyl)methoxy group, a (4-methylphenyl)methoxy group, a (2,3-dimethylphenyl)methoxy group, a (2,4-dimethylphenyl)methoxy group, a (2,5-dimethylphenyl)methoxy group, a (2,6-dimethylphenyl)methoxy group, a (3,4-dimethylphenyl)methoxy group, a (3,5-dimethylphenyl)methoxy group, a (2,3,4-trimethylphenyl)methoxy group, a (2,3,5-trimethylphenyl)methoxy group and a benzyloxy group.

More preferred is a methoxy group, an ethoxy group, an isopropoxy group, a tert-butyl group, an isobutoxy group, a phenoxy group, a 2,6-di(tert-butyl)phenoxy group or a benzyloxy group; further preferred is a methoxy group, a phenoxy group, a 2,6-di(tert-butyl)phenoxy group or a benzyloxy group; and particularly preferred is a methoxy group or a phenoxy group.

$X^1$  is more preferably a chlorine atom, a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a benzyl group, an allyl group, a methallyl group, a methoxy group, an ethoxy group or a phenoxy group, and further preferably a chlorine atom, a methyl group, a methoxy group or a phenoxy group.

In the formula [4], respective numbers of a and b depend upon the valency of  $M^2$ .

Examples of the metal compound represented by the formula [4], wherein  $M^2$  is a titanium atom, are dimethylsilylenebis(cyclopentadienyl)titanium dichloride, dimethylsilylenebis(2-methylcyclopentadienyl) titanium dichloride, dimethylsilylenebis(3-methylcyclopentadienyl) titanium dichloride,

dimethylsilylenebis(2-n-butylcyclopentadienyl) titanium  
dichloride, dimethylsilylenebis(3-n-butylcyclopentadienyl)  
titanium dichloride,  
dimethylsilylenebis(2,3-dimethylcyclopentadienyl) titanium  
5 dichloride,  
dimethylsilylenebis(2,4-dimethylcyclopentadienyl) titanium  
dichloride,  
dimethylsilylenebis(2,5-dimethylcyclopentadienyl) titanium  
dichloride,  
10 dimethylsilylenebis(3,4-dimethylcyclopentadienyl) titanium  
dichloride,  
dimethylsilylenebis(2,3-ethylmethylcyclopentadienyl)  
titanium dichloride,  
dimethylsilylenebis(2,4-ethylmethylcyclopentadienyl)  
15 titanium dichloride,  
dimethylsilylenebis(2,5-ethylmethylcyclopentadienyl)  
titanium dichloride,  
dimethylsilylenebis(3,5-ethylmethylcyclopentadienyl)  
titanium dichloride,  
20 dimethylsilylenebis(2,3,4-trimethylcyclopentadienyl)  
titanium dichloride,  
dimethylsilylenebis(2,3,5-trimethylcyclopentadienyl)  
titanium dichloride,  
dimethylsilylenebis(tetramethylcyclopentadienyl) titanium  
25 dichloride, dimethylsilylenebis(indenyl)titanium dichloride,  
dimethylsilylenebis(4,5,6,7-tetrahydroindenyl) titanium  
dichloride,  
dimethylsilylene(cyclopentadienyl)(indenyl)titanium  
dichloride, dimethylsilylene(methylcyclopentadienyl)  
30 (indenyl)titanium dichloride,

dimethylsilylene(n-butylcyclopentadienyl)(indenyl)  
titanium dichloride,

dimethylsilylene(tetramethylcyclopentadienyl)  
(indenyl)titanium dichloride,

5 dimethylsilylene(cyclopentadienyl)(fluorenyl) titanium  
dichloride,

dimethylsilylene(methylcyclopentadienyl)(fluorenyl)  
titanium dichloride,

10 dimethylsilylene(n-butylcyclopentadienyl)(fluorenyl)  
titanium dichloride,

dimethylsilylene(tetramethylcyclopentadienyl) (fluorenyl)  
titanium dichloride, and

dimethylsilylene(indenyl)(fluorenyl)titanium dichloride;

and compounds obtained by changing "dimethylsilylene" in the  
15 above compounds to "diethylsilylene", "diphenylsilylene" or  
"dimethoxysilylene".

Further examples of the metal compound represented by  
the formula [4], wherein  $M^2$  is a titanium atom, are

bis(cyclopentadienyl)titanium dichloride,

20 bis(methylcyclopentadienyl)titanium dichloride,

bis(n-butylcyclopentadienyl)titanium dichloride,

bis(dimethylcyclopentadienyl)titanium dichloride,

bis(ethylmethylcyclopentadienyl)titanium dichloride,

bis(trimethylcyclopentadienyl)titanium dichloride,

25 bis(tetramethylcyclopentadienyl)titanium dichloride,

bis(pentamethylcyclopentadienyl)titanium dichloride;

bis(indenyl)titanium dichloride,

bis(4,5,6,7-tetrahydroindenyl)titanium dichloride,

bis(fluorenyl)titanium dichloride,

30 bis(2-phenylindenyl)titanium dichloride,

bis[2-(bis-3,5-trifluoromethylphenyl)indenyl] titanium  
 dichloride, bis[2-(4-tert-butylphenyl)indenyl]titanium  
 dichloride,  
 bis[2-(4-trifluoromethylphenyl)indenyl]titanium dichloride,  
 5 bis[2-(4-methylphenyl)indenyl]titanium dichloride,  
 bis[2-(3,5-dimethylphenyl)indenyl]titanium dichloride,  
 bis[2-(pentafluorophenyl)indenyl]titanium dichloride,  
 cyclopentadienyl(pentamethylcyclopentadienyl) titanium  
 dichloride, cyclopentadienyl(indenyl) titanium dichloride,  
 10 cyclopentadienyl(fluorenyl) titanium dichloride,  
 indenyl(fluorenyl)titanium dichloride,  
 pentamethylcyclopentadienyl (indenyl)titanium dichloride,  
 pentamethylcyclopentadienyl(fluorenyl)titanium dichloride,  
 cyclopentadienyl(2-phenylindenyl)titanium dichloride,  
 15 pentamethylcyclopentadienyl(2-phenylindenyl)titanium  
 dichloride, ethylenebis(cyclopentadienyl)titanium  
 dichloride, ethylenebis(2-methylcyclopentadienyl)titanium  
 dichloride, ethylenebis(3-methylcyclopentadienyl)titanium  
 dichloride, ethylenebis(2-n-butylcyclopentadienyl)titanium  
 20 dichloride, ethylenebis(3-n-butylcyclopentadienyl)titanium  
 dichloride,  
 ethylenebis(2,3-dimethylcyclopentadienyl)titanium  
 dichloride,  
 ethylenebis(2,4-dimethylcyclopentadienyl)titanium  
 25 dichloride,  
 ethylenebis(2,5-dimethylcyclopentadienyl)titanium  
 dichloride,  
 ethylenebis(3,4-dimethylcyclopentadienyl)titanium  
 dichloride,  
 30 ethylenebis(2,3-ethylmethylcyclopentadienyl)titanium

dichloride,  
 ethylenebis(2,4-ethylmethylcyclopentadienyl)titanium  
 dichloride,  
 ethylenebis(2,5-ethylmethylcyclopentadienyl)titanium  
 5 dichloride,  
 ethylenebis(3,5-ethylmethylcyclopentadienyl)titanium  
 dichloride,  
 ethylenebis(2,3,4-trimethylcyclopentadienyl)titanium  
 dichloride,  
 10 ethylenebis(2,3,5-trimethylcyclopentadienyl)titanium  
 dichloride, ethylenebis(tetramethylcyclopentadienyl)  
 titanium dichloride, ethylenebis(indenyl)titanium dichloride,  
 ethylenebis(4,5,6,7-tetrahydroindenyl)titanium dichloride,  
 ethylenebis(2-phenylindenyl)titanium dichloride,  
 15 ethylenebis(fluorenyl)titanium dichloride,  
 ethylene(cyclopentadienyl)  
 (pentamethylcyclopentadienyl)titanium dichloride,  
 ethylene(cyclopentadienyl)(indenyl)titanium dichloride,  
 ethylene(methylcyclopentadienyl) (indenyl)titanium  
 20 dichloride,  
 ethylene(n-butylcyclopentadienyl)(indenyl)titanium  
 dichloride, ethylene(tetramethylcyclopentadienyl)  
 (indenyl)titanium dichloride,  
 ethylene(cyclopentadienyl)(fluorenyl)titanium dichloride,  
 25 ethylene(methylcyclopentadienyl) (fluorenyl)titanium  
 dichloride, ethylene  
 (pentamethylcyclopentadienyl)(fluorenyl)titanium  
 dichloride, ethylene(n-butylcyclopentadienyl)  
 (fluorenyl)titanium dichloride, ethylene  
 30 (tetramethylpentadienyl)(fluorenyl)titanium dichloride,

ethylene(indenyl)(fluorenyl)titanium dichloride,  
isopropylidenebis(cyclopentadienyl) titanium dichloride,  
isopropylidenebis(2-methylcyclopentadienyl)titanium  
dichloride,  
5 isopropylidenebis(3-methylcyclopentadienyl)titanium  
dichloride,  
isopropylidenebis(2-n-butylcyclopentadienyl)titanium  
dichloride,  
isopropylidenebis(3-n-butylcyclopentadienyl)titanium  
10 dichloride,  
isopropylidenebis(2,3-dimethylcyclopentadienyl) titanium  
dichloride,  
isopropylidenebis(2,4-dimethylcyclopentadienyl) titanium  
dichloride,  
15 isopropylidenebis(2,5-dimethylcyclopentadienyl) titanium  
dichloride,  
isopropylidenebis(3,4-dimethylcyclopentadienyl) titanium  
dichloride,  
isopropylidenebis(2,3-ethylmethylcyclopentadienyl)  
20 titanium dichloride,  
isopropylidenebis(2,4-ethylmethylcyclopentadienyl)  
titanium dichloride,  
isopropylidenebis(2,5-ethylmethylcyclopentadienyl)  
titanium dichloride,  
25 isopropylidenebis(3,5-ethylmethylcyclopentadienyl)  
titanium dichloride,  
isopropylidenebis(2,3,4-trimethylcyclopentadienyl)  
titanium dichloride,  
isopropylidenebis(2,3,5-trimethylcyclopentadienyl)  
30 titanium dichloride,



isopropylidenebis(tetramethylcyclopentadienyl) titanium  
 dichloride, isopropylidenebis(indenyl) titanium dichloride,  
 isopropylidenebis(4,5,6,7-tetrahydroindenyl)titanium  
 dichloride, isopropylidenebis(2-phenylindenyl)titanium  
 5 dichloride, isopropylidenebis(fluorenyl)titanium dichloride,  
 isopropylidene(cyclopentadienyl)  
 (tetramethylcyclopentadienyl)titanium dichloride,  
 isopropylidene(cyclopentadienyl)(indenyl)titanium  
 dichloride, isopropylidene(methylcyclopentadienyl)  
 10 (indenyl)titanium dichloride,  
 isopropylidene(n-butylcyclopentadienyl)(indenyl) titanium  
 dichloride, isopropylidene(tetramethylcyclopentadienyl)  
 (indenyl)titanium dichloride, isopropylidene  
 (cyclopentadienyl)(fluorenyl)titanium dichloride,  
 15 isopropylidene(methylcyclopentadienyl)(fluorenyl) titanium  
 dichloride,  
 isopropylidene(n-butylcyclopentadienyl)(fluorenyl)  
 titanium dichloride,  
 isopropylidene(tetramethylcyclopentadienyl)  
 20 (fluorenyl)titanium dichloride, isopropylidene  
 (indenyl)(fluorenyl)titanium dichloride,  
 cyclopentadienyl(dimethylamido)titanium dichloride,  
 cyclopentadienyl(phenoxy)titanium dichloride,  
 cyclopentadienyl(2,6-dimethylphenyl)titanium dichloride,  
 25 cyclopentadienyl(2,6-diisopropylphenyl)titanium dichloride,  
 cyclopentadienyl(2,6-di-tert-butylphenyl)titanium  
 dichloride,  
 pentamethylcyclopentadienyl(2,6-dimethylphenyl)titanium  
 dichloride,  
 30 pentamethylcyclopentadienyl(2,6-diisopropylphenyl)

titanium dichloride,  
 pentamethylcyclopentadienyl(2,6-di-tert-butylphenyl)  
 titanium dichloride, indenyl(2,6-diisopropylphenyl)titanium  
 dichloride, fluorenyl (2,6-diisopropylphenyl)titanium  
 5 dichloride,  
 (tert-butylamido)tetramethylcyclopentadienyl-1,2-  
 ethanediyltitanium dichloride,  
 (methylamido)tetramethylcyclopentadienyl-1,2-  
 ethanediyltitanium dichloride,  
 10 (ethylamido)tetramethylcyclopentadienyl-1,2-  
 ethanediyltitanium dichloride,  
 (tert-butylamido)tetramethylcyclopentadienyl  
 dimethylsilanetitanium  
 dichloride, (benzylamido)tetramethylcyclopentadienyl  
 15 dimethylsilanetitanium dichloride,  
 (phenylphosphido)tetramethylcyclopentadienyl  
 dimethylsilanetitanium dichloride,  
 (tert-butylamido)indenyl-1,2-ethanediyltitanium dichloride,  
 (tert-butylamido)tetrahydroindenyl-1,2-ethanediyl titanium  
 20 dichloride,  
 (tert-butylamido)fluorenyl-1,2-ethanediyltitanium  
 dichloride, (tert-butylamido)indenyldimethylsilanetitanium  
 dichloride,  
 (tert-butylamido)tetrahydroindenyldimethylsilane titanium  
 25 dichloride,  
 (tert-butylamido)fluorenyldimethylsilanetitanium  
 dichloride,  
 (dimethylaminomethyl)tetramethylcyclopentadienyl  
 titanium(III) dichloride,  
 30 (dimethylaminoethyl)tetramethylcyclopentadienyl

- titanium(III) dichloride,  
 (dimethylaminopropyl)tetramethylcyclopentadienyl-titanium  
 (III) dichloride,  
 (N-pyrrolidinyethyl)tetramethylcyclopentadienyl-titanium  
 5 dichloride,  
 (B-dimethylaminoborabenzene)cyclopentadienylzirconium  
 dichloride,  
 cyclopentadienyl(9-mesitylboraanthracenyl)zirconium  
 dichloride,  
 10 2,2'-thiobis(4-methyl-6-tert-butylphenoxy)titanium  
 dichloride,  
 2,2'-thiobis[4-methyl-6-(1-methylethyl)phenoxy] titanium  
 dichloride, 2,2'-thiobis[4,6-dimethylphenoxy]titanium  
 dichloride,  
 15 2,2'-methylenebis(4-methyl-6-tert-butylphenoxy) titanium  
 dichloride,  
 2,2'-ethylenebis(4-methyl-6-tert-butylphenoxy) titanium  
 dichloride, 2,2'-sulfinylbis(4-methyl-6-tert-butylphenoxy)  
 titanium dichloride,  
 20 2,2'-(4,4',6,6'-tetra-tert-butyl-1,1'-biphenoxy) titanium  
 dichloride, (di-tert-butyl-1,3-propanediamido)titanium  
 dichloride, (dicyclohexyl-1,3-propanediamido)titanium  
 dichloride,  
 [bis(trimethylsilyl)-1,3-propanediamido]titanium  
 25 dichloride,  
 [bis(tert-butyldimethylsilyl)-1,3-propanediamido]  
 titanium dichloride,  
 [bis(2,6-dimethylphenyl)-1,3-propanediamido]titanium  
 dichloride,  
 30 [bis(2,6-diisopropylphenyl)-1,3-propanediamido] titanium

dichloride,

[bis(2,6-di-tert-butylphenyl)-1,3-propanediamido]

titanium dichloride,

[bis(triisopropylsilyl)naphthalenediamido]titanium

5 dichloride,

[bis(trimethylsilyl)naphthalenediamido]titanium dichloride,

[bis(tert-butyldimethylsilyl)naphthalenediamido] titanium  
dichloride,

[bis(tert-butyldimethylsilyl)naphthalenediamido]titanium

10 dibromide, cyclopentadienyttitanium trichloride,

pentamethylcyclopentadienyttitanium trichloride,

[hydrotris(3,5-dimethylpyrazolyl)borate]titanium  
trichloride,

[hydrotris(3,5-diethylpyrazolyl)borate]titanium

15 trichloride,

[hydrotris(3,5-di-tert-butylpyrazolyl)borate] titanium

trichloride, [tris(3,5-dimethylpyrazolyl)methyl]titanium

trichloride, [tris(3,5-diethylpyrazolyl)methyl]titanium

trichloride and

20 [tris(3,5-di-tert-butylpyrazolyl)methyl]titanium

trichloride.

Still further examples of the metal compound represented  
by the formula [4], wherein  $M^2$  is a titanium atom, are compounds  
in which "dichloride" in the abnove-mentioned compounds is  
25 changed to "difluoride", "dibromide", "diiodide", "dimethyl",  
"diethyl", "diisopropyl", "diphenyl", "dibenzyl",  
"dimethoxide", "diethoxide", "di-n-propoxide",  
"diisopropoxide", "di-n-butoxide", "diisobutoxide",  
"di-tert-butoxide", "diphenoxide" or  
30 "di(2,6-di-tert-butylphenoxide", and compounds in which

"trichloride" in the above-mentioned compounds is changed to "trifluoride", "tribromide", "triiodide", "trimethyl", "triethyl", "triisopropyl", "triphenyl", "tribenzyl", "trimethoxide", "triethoxide", "tri-n-propoxide",  
 5 "triisopropoxide", "tri-n-butoxide", "triisobutoxide", "tri-tert-butoxide", "triphenoxide" or "tri(2,6-di-tert-butylphenoxide".

Examples of the metal compound represented by the formula [4], wherein  $M^2$  is a zirconium atom or a hafnium atom, are those  
 10 in which a "titanium atom" in the above-mentioned compounds is changed to a "zirconium atom" or a "hafnium atom".

Examples of the metal compound represented by the formula [4], wherein  $M^2$  is a nickel atom, are  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 15 dimethyloxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 diethyloxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 di-n-propyloxazoline]nickel dibromide,  
 20 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 diisopropyloxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 dicyclohexyloxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-  
 25 dimethoxyoxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-diethoxyoxazoline]  
 nickel dibromide,  
 2,2'-methylenebis[(4R)-4-phenyl-5,5'-diphenyloxazoline]  
 nickel dibromide,  
 30 methylenebis[(4R)-4-methyl-5,5'-di-(2-methylphenyl)]

oxazoline]nickel dibromide,  
 methylenebis[(4R)-4-methyl-5,5'-di-(3-methylphenyl)  
 oxazoline]nickel dibromide,  
 methylenebis[(4R)-4-methyl-5,5'-di-(4-methylphenyl)oxazol  
 5 ine]nickel dibromide,  
 methylenebis[(4R)-4-methyl-5,5'-di-(2-methoxyphenyl)  
 oxazoline]nickel dibromide,  
 methylenebis[(4R)-4-methyl-5,5'-di-(3-methoxyphenyl)  
 oxazoline]nickel dibromide,  
 10 methylenebis[(4R)-4-methyl-5,5'-di-(4-methoxyphenyl)  
 oxazoline]nickel dibromide,  
 methylenebis[spiro{(4R)-4-methyloxazoline-5,1'-  
 cyclobutane}]nickel dibromide,  
 methylenebis[spiro{(4R)-4-methyloxazoline-5,1'-  
 15 cyclopentane}]nickel dibromide,  
 methylenebis[spiro{(4R)-4-methyloxazoline-5,1'-  
 cyclohexane}]nickel dibromide,  
 methylenebis[spiro{(4R)-4-methyloxazoline-5,1'-  
 cycloheptane}]nickel dibromide,  
 20 2,2'-methylenebis[(4R)-4-isopropyl-5,5-dimethyloxazoline]  
 nickel dibromide,  
 2,2'-methylenebis[(4R)-4-isopropyl-5,5-diethyloxazoline]  
 nickel dibromide,  
 2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-n-  
 25 propyloxazoline]nickel dibromide,  
 methylenebis[(4R)-4-isopropyl-5,5-diisopropyloxazoline]  
 nickel dibromide, 2,2'-methylenebis[(4R)-4-isopropyl-5,5-  
 dicyclohexyloxazoline]nickel dibromide,  
 2,2'-methylenebis[(4R)-4-isopropyl-5,5-diphenyloxazoline]  
 30 nickel dibromide,

- 2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(2-methylphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(3-methylphenyl)oxazoline]nickel dibromide,  
5 2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(4-methylphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(2-methoxyphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(3-methoxyphenyl)oxazoline]nickel dibromide,  
10 2,2'-methylenebis[(4R)-4-isopropyl-5,5-di-(4-methoxyphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-isopropylloxazoline-5,1'-cyclobutane}]nickel dibromide,  
15 2,2'-methylenebis[spiro{(4R)-4-isopropylloxazoline-5,1'-cyclopentane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-isopropylloxazoline-5,1'-cyclohexane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-isopropylloxazoline-5,1'-cycloheptane}]nickel dibromide,  
20 2,2'-methylenebis[(4R)-4-isobutyl-5,5-dimethyloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isobutyl-5,5-diethyloxazoline]nickel dibromide,  
25 2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-n-propyloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isobutyl-5,5-diisopropylloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-isobutyl-5,5-dicyclohexyloxazoline]nickel dibromide,  
30

2,2'-methylenebis[(4R)-4-isobutyl-5,5-diphenyloxazoline]  
nickel dibromide,

2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-(2-methylphenyl)  
oxazoline]nickel dibromide,

5 2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-(3-methylphenyl)  
oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-(4-methylphenyl)  
oxazoline]nickel dibromide,

10 2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-  
(2-methoxyphenyl)oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-  
(3-methoxyphenyl)oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-isobutyl-5,5-di-  
(4-methoxyphenyl)oxazoline]nickel dibromide,

15 2,2'-methylenebis[spiro{(4R)-4-isobutyloxazoline-5,1'-  
cyclobutane}]nickel dibromide,

2,2'-methylenebis[spiro{(4R)-4-isobutyloxazoline-5,1'-  
cyclopentane}]nickel dibromide,

20 2,2'-methylenebis[spiro{(4R)-4-isobutyloxazoline-5,1'-  
cyclohexane}]nickel dibromide,

2,2'-methylenebis[spiro{(4R)-4-isobutyloxazoline-5,1'-  
cycloheptane}]nickel dibromide,

2,2'-methylenebis[(4R)-4-tert-butyl-5,5-  
dimethyloxazoline]nickel dibromide,

25 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-diethyloxazoline]  
nickel dibromide,

2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-n-  
propyloxazoline]nickel dibromide,

30 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-  
diisopropyloxazoline]nickel dibromide,



- 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-diphenyloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-tert-butyl-5,5-dicyclohexyloxazoline]nickel dibromide,  
5 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(2-methylphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(3-methylphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(4-methylphenyl)oxazoline]nickel dibromide,  
10 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(2-methoxyphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(3-methoxyphenyl)oxazoline]nickel dibromide,  
15 2,2'-methylenebis[(4R)-4-tert-butyl-5,5-di-(4-methoxyphenyl)oxazoline]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-tert-butyloxazoline-5,1'-cyclobutane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-tert-butyloxazoline-5,1'-cyclopentane}]nickel dibromide,  
20 2,2'-methylenebis[spiro{(4R)-4-tert-butyloxazoline-5,1'-cyclohexane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-tert-butyloxazoline-5,1'-cycloheptane}]nickel dibromide,  
25 2,2'-methylenebis[(4R)-4-phenyl-5,5-dimethyloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-diethyloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-n-propyloxazoline]  
30 nickel dibromide,

2,2'-methylenebis[(4R)-4-phenyl-5,5-diisopropylloxazoline]  
nickel dibromide, 2,2'-methylenebis[(4R)-4-phenyl-5,5-  
dicyclohexylloxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-diphenyl]oxazoline]  
5 nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(2-methylphenyl)  
oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(3-methylphenyl)  
oxazoline]nickel dibromide,  
10 2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(4-methylphenyl)  
oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(2-methoxyphenyl)  
oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(3-methoxyphenyl)  
15 oxazoline]nickel dibromide,  
2,2'-methylenebis[(4R)-4-phenyl-5,5-di-(4-methoxyphenyl)  
oxazoline]nickel dibromide,  
methylenebis[spiro{(4R)-4-phenylloxazoline-5,1'-  
cyclobutane}]nickel dibromide,  
20 2,2'-methylenebis[spiro{(4R)-4-phenylloxazoline-5,1'-  
cyclopentane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-phenylloxazoline-5,1'-  
cyclohexane}]nickel dibromide,  
2,2'-methylenebis[spiro{(4R)-4-phenylloxazoline-5,1'-  
25 cycloheptane}]nickel dibromide,  
2,2'-methylenebis[(4R)-4-benzyl-5,5-dimethylloxazoline]  
nickel dibromide,  
2,2'-methylenebis[(4R)-4-benzyl-5,5-diethylloxazoline]  
nickel dibromide,  
30 2,2'-methylenebis[(4R)-4-benzyl-5,5-di-n-propylloxazoline]

nickel dibromide,

2,2'-methylenebis[(4R)-4-benzyl-5,5-diisopropylloxazoline]

nickel dibromide, 2,2'-methylenebis[(4R)-4-benzyl-5,5-dicyclohexylloxazoline]nickel dibromide,

5 2,2'-methylenebis[(4R)-4-benzyl-5,5-diphenyl]oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(2-methylphenyl)oxazoline]nickel dibromide,

10 2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(3-methylphenyl)oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(4-methylphenyl)oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(2-methoxyphenyl)oxazoline]nickel dibromide,

15 2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(3-methoxyphenyl)oxazoline]nickel dibromide,

2,2'-methylenebis[(4R)-4-benzyl-5,5-di-(4-methoxyphenyl)oxazoline]nickel dibromide,

20 2,2'-methylenebis[spiro{(4R)-4-benzyloxazoline-5,1'-cyclobutane}]nickel dibromide,

2,2'-methylenebis[spiro{(4R)-4-benzyloxazoline-5,1'-cyclopentane}]nickel dibromide,

2,2'-methylenebis[spiro{(4R)-4-benzyloxazoline-5,1'-cyclohexane}]nickel dibromide, and

25 2,2'-methylenebis[spiro{(4R)-4-benzyloxazoline-5,1'-cycloheptane}]nickel dibromide; and antipodes and diastereomers of the above-mentioned compounds. Further examples thereof

are [hydrotris(3,5-dimethylpyrazolyl)borate]nickel bromide,

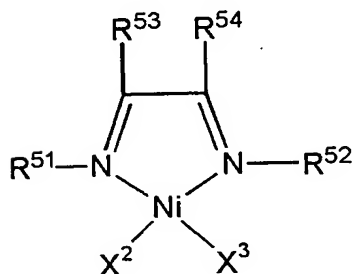
[hydrotris(3,5-diethylpyrazolyl)borate]nickel bromide, and

30 [hydrotris(3,5-di-tert-butylpyrazolyl)borate]nickel

bromide.

Still further examples of the metal compound represented by the formula [4], wherein  $M^2$  is a nickel atom, are compounds in which "dibromide" in the above-mentioned compounds is changed to "difluoride", "dichloride", "diiodide", "dimethyl", "diethyl", "diisopropyl", "diphenyl", "dibenzyl", "dimethoxide", "diethoxide", "di-n-propoxide", "diisopropoxide", "di-n-butoxide", "diisobutoxide", "di-tert-butoxide", "diphenoxide" or "di(2,6-di-tert-butylphenoxide)".

A further example of the metal compound represented by the formula [4], wherein  $M^2$  is a nickel atom, is a compound represented by the following formula [7]:



[ 7 ]

wherein each of  $R^{51}$  and  $R^{52}$  is a 2,6-diisopropylphenyl group; each of  $R^{53}$  and  $R^{54}$  is independently of each other a hydrogen atom or a methyl group, or  $R^{53}$  and  $R^{54}$  are combined to form an acenaphtene group; and each of  $X^2$  and  $X^3$  is independently of each other a fluorine atom, a chlorine atom, a bromine atom, an iodine atom, a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a phenyl group, a benzyl group, a methoxy group, an ethoxy group, a n-propoxy group, an isopropoxy group, a n-butoxy group, an isobutoxy group, or a phenoxy group.

Further examples of the metal compound represented by the formula [4] are compounds in which a "nickel atom" in the above-mentioned nickel compounds is changed to a "palladium atom", a "cobalt atom", a "rhodium atom" or a "ruthenium atom".

5        Examples of the metal compound represented by the formula [4], wherein  $M^2$  is an iron atom, are  
 2,6-bis-[1-(2,6-dimethylphenylimino)ethyl]pyridineiron dichloride, 2,6-bis-[1-(2,6-diisopropylphenylimino)ethyl]pyridineiron dichloride,  
 10    2,6-bis-[1-(2-tert-butylphenylimino)ethyl]pyridineiron dichloride, [hydrotris(3,5-dimethylpyrazolyl)borate]iron chloride, [hydrotris(3,5-diethylpyrazolyl) borate]iron chloride, and  
 [hydrotris(3,5-di-tert-butylpyrazolyl)borate]iron  
 15    chloride; and compounds in which "dichloride" in the above-mentioned iron compounds is changed to "dibromide", "difluoride", "diiodide", "dimethyl", "diethyl", "diisopropyl", "diphenyl", "dibenzyl", "dimethoxide", "diethoxide", "di-n-propoxide", "diisopropoxide",  
 20    "di-n-butoxide", "diisobutoxide", "di-tert-butoxide", "diphenoxide" or "di(2,6-di-tert-butylphenoxide)".

Further examples of the metal compound represented by the formula [4] are compounds obtained by changing an "iron atom" in the above-mentioned iron compounds to a "cobalt atom" or a "nickel atom".

Examples of the  $\mu$ -oxo type metal compound of the metal compound represented by the formula [4] are  
 $\mu$ -oxobis[isopropylidene  
 (cyclopentadienyl)(2-phenoxy)titanium chloride],  
 30     $\mu$ -oxobis[isopropylidene(cyclopentadienyl)(3-tert-butyl-5-

methyl-2-phenoxy)titanium chloride],

$\mu$ -oxobis[isopropylidene(methylcyclopentadienyl)  
(2-phenoxy)titanium chloride],

$\mu$ -oxobis[isopropylidene(methylcyclopentadienyl)(3-tert-  
5 butyl-5-methyl-2-phenoxy)titanium chloride],

$\mu$ -oxobis[isopropylidene(tetramethylcyclopentadienyl)  
(2-phenoxy)titanium chloride],

$\mu$ -oxobis[isopropylidene (tetramethylcyclopentadienyl)  
(3-tert-butyl-5-methyl-2-phenoxy)titanium methoxide],

10  $\mu$ -oxobis [dimethylsilylene(cyclopentadienyl)  
(2-phenoxy)titanium methoxide],

$\mu$ -oxobis[dimethylsilylene(cyclopentadienyl)  
(3-tert-butyl-5-methyl-2-phenoxy)titanium chloride],

15  $\mu$ -oxobis[dimethylsilylene(methylcyclopentadienyl)  
(2-phenoxy)titanium chloride],

$\mu$ -oxobis[dimethylsilylene(methylcyclopentadienyl)  
(3-tert-butyl-5-methyl-2-phenoxy)titanium chloride],

$\mu$ -oxobis[dimethylsilylene(tetramethylcyclopentadienyl)  
(2-phenoxy)titanium chloride], and

20  $\mu$ -oxobis[dimethylsilylene(tetramethylcyclopentadienyl)  
(3-tert-butyl-5-methyl-2-phenoxy)titanium chloride].

Further examples are compounds obtained by changing "chloride"  
in these compounds to "fluoride", "bromide", "iodide", "methyl",  
"ethyl", "isopropyl", "phenyl", "benzyl", "methoxide",  
25 "ethoxide", "n-propoxide", "isopropoxide", "n-butoxide",  
"isobutoxide", "tert-butoxide", "phenoxide" or  
"2,6-di-tert-butylphenoxide".

Further examples of the  $\mu$ -oxo type metal compound of  
the metal compound represented by the formula [4] are

30 di- $\mu$ -oxobis[isopropylidene(cyclopentadienyl)

(2-phenoxy)titanium],  
 di- $\mu$ -oxobis[isopropylidene(cyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium],  
 di- $\mu$ -oxobis[isopropylidene(methylcyclopentadienyl)  
 5 (2-phenoxy)titanium],  
 di- $\mu$ -oxobis[isopropylidene(methylcyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium],  
 di- $\mu$ -oxobis[isopropylidene  
 (tetramethylcyclopentadienyl)(2-phenoxy)titanium],  
 10 di- $\mu$ -oxobis[isopropylidene (tetramethylcyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium],  
 di- $\mu$ -oxobis [dimethylsilylene(cyclopentadienyl)  
 (2-phenoxy)titanium],  
 di- $\mu$ -oxobis[dimethylsilylene(cyclopentadienyl)  
 15 (3-tert-butyl-5-methyl-2-phenoxy)titanium],  
 di- $\mu$ -oxobis[dimethylsilylene(methylcyclopentadienyl)  
 (2-phenoxy)titanium],  
 di- $\mu$ -oxobis[dimethylsilylene(methylcyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium],  
 20 di- $\mu$ -oxobis[dimethylsilylene(tetramethylcyclopentadienyl)  
 (2-phenoxy)titanium] and  
 di- $\mu$ -oxobis[dimethylsilylene(tetramethylcyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium].

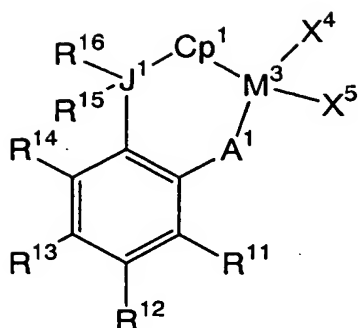
Other examples of the compound (B), wherein the metal  
 25 atom is a nickel atom, are nickel chloride, nickel bromide,  
 nickel iodide, nickel sulfate, nickel nitrate, nickel  
 perchlorate, nickel acetate, nickel trifluoroacetate, nickel  
 cyanide, nickel oxalate, nickel acetylacetonate, bis(allyl)  
 nickel, bis(1,5-cyclooctadiene)nickel,  
 30 dichloro(1,5-cyclooctadiene) nickel,

dichlorobis(acetonitrile)nickel,  
dichlorobis(benzonitrile)nickel, carbonyl  
tris(triphenylphosphine)nickel,  
dichlorobis(triethylphosphine)nickel, di-acetobis  
5 (triphenylphosphine)nickel,  
tetrakis(triphenylphosphine)nickel, dichloro[1,2- bis  
(diphenylphosphino)ethane]nickel,  
bis[1,2-bis(diphenylphosphino)ethane]nickel,  
dichloro[1,3-bis(diphenylphosphino)propane]nickel,  
10 bis[1,3-bis(diphenylphosphino)propane]nickel, tetraamine  
nickel nitrate, tetrakis(acetonitrile)nickel  
tetrafluoroborate and nickel phthalocyanine.

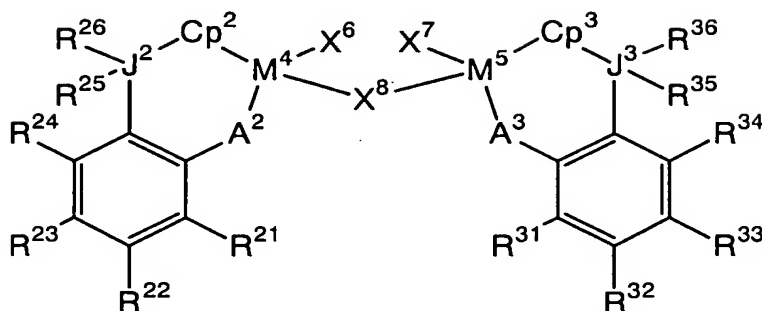
Examples of the compound (B), wherein the metal atom  
is a vanadium atom, are vanadium acetylacetonate, vanadium  
15 tetrachloride and vanadium oxy trichloride. An example thereof,  
wherein the metal atom is a samarium atom, is  
bis(pentamethylcyclopentadienyl)samarium  
methyltetrahydrofuran. An example thereof, wherein the metal  
atom is an ytterbium atom, is  
20 bis(pentamethylcyclopentadienyl)ytterbium  
methyltetrahydrofuran.

Examples of the compound (B) used in order to obtain  
the catalyst in accordance with the present invention are those  
represented by the following formulas [8] to [10]:





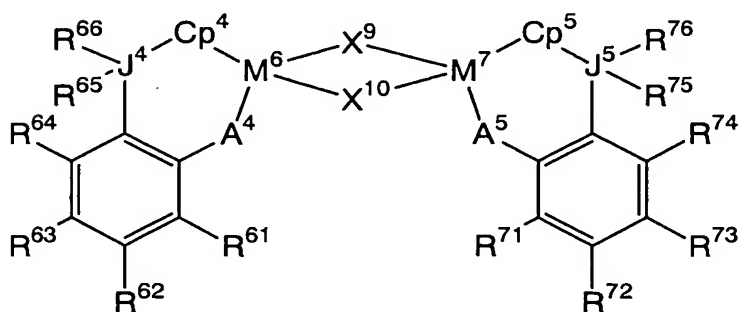
[8]



[9]

5

and



[10]

10. wherein respective  $M^3$  to  $M^7$  are independently an atom of the Group 4 of the periodic table of the elements; respective  $A^1$  to  $A^5$  are independently an atom of the Group 16 of the periodic table of the elements; respective  $J^1$  to  $J^5$  are an atom of the Group 16 of the periodic table of the elements; respective
- 15  $Cp^1$  to  $Cp^5$  are a group having a cyclopentadienyl anion skeleton;

respective  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  are independently a hydrogen atom, a halogen atom, a hydrocarbon group, a substituted silyl group, a hydrocarbon oxy group, a di-substituted amino group, a hydrocarbon thio group or a hydrocarbon seleno group, and they may link to form a single ring or a plurality of rings which may be aromatic ring(s) or non-aromatic ring(s); and respective  $X^8$  to  $X^{10}$  are an atom of the Group 16 of the periodic table of the elements.

In the formulae [8] to [10], the metal represented by  $M^3$  to  $M^7$  are a metal atom of the Group 4 of the Periodic Table (IUPAC 1985), and for example, a titanium atom, a zirconium atom and a hafnium atom are exemplified. A titanium atom and a zirconium atom are preferred.

Examples of the group having a cyclopentadienyl type anion skeleton as  $Cp^1$  to  $Cp^5$  are

- an  $\eta^5$ -(substituted)cyclopentadienyl group,
- an  $\eta^5$ -(substituted)indenyl group, and
- an  $\eta^5$ -(substituted)fluorenyl group. Specific examples thereof are an  $\eta^5$ -cyclopentadienyl group,
- an  $\eta^5$ -methylcyclopentadienyl group,
- an  $\eta^5$ -dimethylcyclopentadienyl group,
- an  $\eta^5$ -trimethylcyclopentadienyl group,
- an  $\eta^5$ -tetramethylcyclopentadienyl group,
- an  $\eta^5$ -ethylcyclopentadienyl group,
- an  $\eta^5$ -n-propylcyclopentadienyl group,
- an  $\eta^5$ -isopropylcyclopentadienyl group,
- an  $\eta^5$ -n-butylcyclopentadienyl group,
- an  $\eta^5$ -sec-butylcyclopentadienyl group,
- an  $\eta^5$ -tert-butylcyclopentadienyl group,

an  $\eta^5$ -phenylcyclopentadienyl group,  
 an  $\eta^5$ -trimethylsilylcyclopentadienyl group,  
 an  $\eta^5$ -tert-butyltrimethylsilylcyclopentadienyl group,  
 an  $\eta^5$ -indenyl group, an  $\eta^5$ -methylindenyl group,  
 5 an  $\eta^5$ -dimethylindenyl group, an  $\eta^5$ -n-propylindenyl group,  
 an  $\eta^5$ -isopropylindenyl group, an  $\eta^5$ -n-butylindenyl group,  
 an  $\eta^5$ -tert-butylindenyl group, an  $\eta^5$ -phenylindenyl group,  
 an  $\eta^5$ -methylphenylindenyl group, an  $\eta^5$ -naphthylindenyl group,  
 an  $\eta^5$ -trimethylsilylindenyl group, an  $\eta^5$ -tetrahydroindenyl  
 10 group, an  $\eta^5$ -fluorenyl group, an  $\eta^5$ -methylfluorenyl group,  
 an  $\eta^5$ -dimethylfluorenyl group, an  $\eta^5$ -tert-butylfluorenyl  
 group, an  $\eta^5$ -di-tert-butylfluorenyl group,  
 an  $\eta^5$ -phenylfluorenyl group, an  $\eta^5$ -diphenylfluorenyl group,  
 an  $\eta^5$ -trimethylsilylfluorenyl group and  
 15 an  $\eta^5$ -bistrimethylsilylfluorenyl group; preferably an  $\eta$   
 $\eta^5$ -cyclopentadienyl group, an  $\eta^5$ -methylcyclopentadienyl group,  
 an  $\eta^5$ -n-butylcyclopentadienyl group,  
 an  $\eta^5$ -tert-butylcyclopentadienyl group,  
 an  $\eta^5$ -tetramethylcyclopentadienyl group,  
 20 an  $\eta^5$ -indenyl group, an  $\eta^5$ -tetrahydroindenyl group and an  $\eta$   
 $\eta^5$ -fluorenyl group.

In  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$   
 and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10], as a halogen atom,  
 a fluorine atom, a chlorine atom, a bromine atom and an iodine  
 25 atom are exemplified, and a chlorine atom or a bromine atom  
 is preferable, and a chlorine atom is more preferable.

In  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$   
 and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10], as a hydrocarbon  
 group, an alkyl group, an aralkyl group and aryl group are  
 30 exemplified.

As the alkyl group, a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, a tert-butyl group, an isobutyl group, a n-pentyl group, a neopentyl group, a tert-pentyl group, a n-hexyl group, a n-octyl group, a n-decyl group, a n-dodecyl group, n-pentadecyl group and a n-eicosyl group are exemplified.

These alkyl groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom.

Examples of such an alkyl group substituted with the halogen atom are a fluoromethyl group, a trifluoromethyl group, a chloromethyl group, a trichloromethyl group, a fluoroethyl group, a pentafluoroethyl group, a perfluoropropyl group, a perfluorobutyl group, a perfluorohexyl group, a perfluorooctyl group, perchloropropyl group, a per chlorobutyl group and perbromopropyl group.

The alkyl group is preferably an alkyl group having 1 to 20 carbon atoms; and more preferably a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, an isobutyl group or a tert-pentyl group.

Examples of the aralkyl group are a benzyl group, a (2-methylphenyl)methyl group, a (3-methylphenyl)methyl group, a (4-methylphenyl)methyl group, a (2,3-dimethylphenyl)methyl group, a (2,4-dimethylphenyl)methyl group, a (2,5-dimethylphenyl)methyl group, a (2,6-dimethylphenyl)methyl group, a (3,4-dimethylphenyl)methyl group, a (3,5-dimethylphenyl)methyl group, a (2,3,4-trimethylphenyl)methyl group, a (2,3,5-trimethylphenyl)methyl group, a

(2,3,6-trimethylphenyl)methyl group, a  
 (3,4,5-trimethylphenyl)methyl group, a  
 (2,4,6-trimethylphenyl)methyl group, a  
 (2,3,4,5-tetramethylphenyl)methyl group, a  
 5 (2,3,4,6-tetramethylphenyl)methyl group, a  
 (2,3,5,6-tetramethylphenyl)methyl group, a  
 (pentamethylphenyl)methyl group, an (ethylphenyl)methyl  
 group, a (n-propylphenyl)methyl group, an  
 (isopropylphenyl)methyl group, a (n-butylphenyl)methyl group,  
 10 a (sec-butylphenyl)methyl group, a (tert-butylphenyl)methyl  
 group, a (n-pentylphenyl)methyl group, a  
 (neopentylphenyl)methyl group, a (n-hexylphenyl)methyl group,  
 a (n-octylphenyl)methyl group, a (n-decylphenyl)methyl group,  
 a (tetradecylphenyl)methyl group, a naphthylmethyl group and  
 15 an anthracenylmethyl group.

The aralkyl group is preferably an aralkyl group having  
 7 to 20 carbon atoms, and more preferably a benzyl group.

Examples of the aryl group are a phenyl group, a 2-tolyl  
 group, a 3-tolyl group, a 4-tolyl group, a 2,3-xylyl group,  
 20 a 2,4-xylyl group, a 2,5-xylyl group, a 2,6-xylyl group, a  
 3,4-xylyl group, a 3,5-xylyl group, a 2,3,4-trimethylphenyl  
 group, a 2,3,5-trimethylphenyl group, a 2,3,6-trimethylphenyl  
 group, a 2,4,6-trimethylphenyl group, a 3,4,5-trimethylphenyl  
 group, a 2,3,4,5-tetramethylphenyl group, a  
 25 2,3,4,6-tetramethylphenyl group, a 2,3,5,6-tetramethylphenyl  
 group, a pentamethylphenyl group, an ethylphenyl group, a  
 n-propylphenyl group, an isopropylphenyl group, a  
 n-butylphenyl group, a sec-butylphenyl group, a  
 tert-butylphenyl group, an isobutylphenyl group, a  
 30 n-pentylphenyl group, a neopentylphenyl group, a n-hexylphenyl

group, a n-octylphenyl group, a n-decylphenyl group, a n-dodecylphenyl group, a n-tetradecylphenyl group, a naphthyl group and an anthracenyl group.

The aryl group is preferably an aryl group having 6 to 20 carbon atoms, and more preferably a phenyl group.

These alkyl, aralkyl and aryl groups above-mentioned as  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10], may be respectively substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

Further, as  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10], the substituted silyl group means a silyl group substituted with a hydrocarbon group, and said hydrocarbon group may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as benzyloxy group.

The hydrocarbon group is preferably an alkyl group having 1 to 20 carbon atoms such as a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, a tert-butyl group, an isobutyl group, a n-pentyl group, a n-hexyl group and a cyclohexyl group, or an aryl group having 6 to 20 carbon atoms such as a phenyl group.

Examples of such a substituted silyl group are a mono-substituted silyl group having 1 to 20 carbon atoms such

as a methylsilyl group, an ethylsilyl group and a phenylsilyl group; a di-substituted silyl group having 2 to 20 carbon atoms such as a dimethylsilyl group, a diethylsilyl group and a diphenylsilyl group; and a tri-substituted silyl group having  
 5 3 to 20 carbon atoms such as a trimethylsilyl group, a triethylsilyl group, a tri-n-propylsilyl group, a triisopropylsilyl group, a tri-n-butylsilyl group, a tri-sec-butylsilyl group, a tri-tert-butylsilyl group, a tri-isobutylsilyl group, a tert-butyl-dimethylsilyl group,  
 10 a tri-n-pentylsilyl group, a tri-n-hexylsilyl group, a tricyclohexylsilyl group and a triphenylsilyl group; and a trimethylsilyl group, a tert-butyl-dimethylsilyl group or a triphenylsilyl group is preferable.

Examples of the hydrocarbonoxy group in as  $X^4$  to  $X^7$ ,  $R^{11}$   
 15 to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] are an alkoxy group, an aralkyloxy group and an aryloxy group.

Examples of the alkoxy group are a methoxy group, an ethoxy group, a n-propoxy group, an isopropoxy group, a n-butoxy group, a sec-butoxy group, a tert-butoxy group, a n-pentoxy group, a neopentoxy group, a n-hexoxy group, a n-octoxy group, a n-dodecoxy group, a n-pentadecoxy group and a n-eicosoxy group. These alkoxy groups may be partially substituted with  
 20 a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

The alkoxy group in  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$   
 30 to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] is

preferably an alkoxy group having 1 to 20 carbon atoms, and more preferably a methoxy group, an ethoxy group, an isopropoxy group or a tert-butyl group.

Examples of the aralkyloxy group are a benzyloxy group, a (2-methylphenyl)methoxy group, a (3-methylphenyl)methoxy group, a (4-methylphenyl)methoxy group, a (2,3-dimethylphenyl)methoxy group, a (2,4-dimethylphenyl)methoxy group, a (2,5-dimethylphenyl)methoxy group, a (2,6-dimethylphenyl)methoxy group, a (3,4-dimethylphenyl)methoxy group, a (3,5-dimethylphenyl)methoxy group, a (2,3,4-trimethylphenyl)methoxy group, a (2,3,5-trimethylphenyl)methoxy group, a (2,3,6-trimethylphenyl)methoxy group, a (2,4,5-trimethylphenyl)methoxy group, a (2,4,6-trimethylphenyl)methoxy group, a (3,4,5-trimethylphenyl)methoxy group, a (2,3,4,5-tetramethylphenyl)methoxy group, a (2,3,4,6-tetramethylphenyl)methoxy group, a (2,3,5,6-tetramethylphenyl)methoxy group, a (pentamethylphenyl)methoxy group, an (ethylphenyl)methoxy group, a (n-propylphenyl)methoxy group, an (isopropylphenyl)methoxy group, (n-butylphenyl)methoxy group, a (sec-butylphenyl)methoxy group, a (tert-butylphenyl)methoxy group, a (n-hexylphenyl)methoxy group, a (n-octylphenyl)methoxy group, a (n-decylphenyl)methoxy group, a naphthylmethoxy group and an anthracenylmethoxy group.

These aralkyloxy groups may be substituted with a halogen



atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

5           The aralkyloxy group in  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] is preferably an aralkyloxy group having 7 to 20 carbon atoms, and more preferably a benzyloxy group.

          Examples of the aryloxy group are a phenoxy group, a  
 10   2-methylphenoxy group, a 3-methylphenoxy group, a  
 4-methylphenoxy group, a 2,3-dimethylphenoxy group, a  
 2,4-dimethylphenoxy group, a 2,5-dimethylphenoxy group, a  
 2,6-dimethylphenoxy group, a 3,4-dimethylphenoxy group, a  
 3,5-dimethylphenoxy group, a 2-tert-butyl-3-methylphenoxy  
 15   group, a 2-tert-butyl-4-methylphenoxy group, a  
 2-tert-butyl-5-methylphenoxy group, a  
 2-tert-butyl-6-methylphenoxy group, a 2,3,4-trimethylphenoxy  
 group, a 2,3,5-trimethylphenoxy group, a  
 2,3,6-trimethylphenoxy group, a 2,4,5-trimethylphenoxy group,  
 20   a 2,4,6-trimethylphenoxy group, a  
 2-tert-butyl-3,4-dimethylphenoxy group, a  
 2-tert-butyl-3,5-dimethylphenoxy group, a  
 2-tert-butyl-3,6-dimethylphenoxy group, a  
 2,6-di-tert-butyl-3-methylphenoxy group, a  
 25   2-tert-butyl-4,5-dimethylphenoxy group, a  
 2,6-di-tert-butyl-4-methylphenoxy group, a  
 3,4,5-trimethylphenoxy group, a 2,3,4,5-tetramethylphenoxy  
 group, a 2-tert-butyl-3,4,5-trimethylphenoxy group, a  
 2,3,4,6-tetramethylphenoxy group, a  
 30   2-tert-butyl-3,4,6-trimethylphenoxy group, a

2,6-di-tert-butyl-3,4-dimethylphenoxy group, a  
 2,3,5,6-tetramethylphenoxy group, a 2-  
 tert-butyl-3,5,6-trimethylphenoxy group, a  
 2,6-di-tert-butyl-3,5-dimethylphenoxy group,  
 5 pentamethylphenoxy group, an ethylphenoxy group, a  
 n-propylphenoxy group, an isopropylphenoxy group, a  
 n-butylphenoxy group, a sec-butylphenoxy group, a  
 tert-butylphenoxy group, a n-hexylphenoxy group, a  
 n-octylphenoxy group, a n-decylphenoxy group, a  
 10 n-tetradecylphenoxy group, a naphthoxy group and an  
 anthracenoxy group.

These aryloxy groups may be substituted with a halogen  
 atom such as a fluorine atom, a chlorine atom, a bromine atom  
 and an iodine atom; an alkoxy group such as a methoxy group  
 15 and an ethoxy group; an aryloxy group such as a phenoxy group;  
 or an aralkyloxy group such as a benzyloxy group.

The aryloxy group in  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$   
 to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] is  
 preferably an aryloxy group having 6 to 20 carbon atoms.

20 The di-substituted amino group in  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  
 $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas  
 [8] to [10] means an amino group substituted with two hydrocarbon  
 groups or silyl groups, and said hydrocarbon group and said  
 silyl group may be substituted with a halogen atom such as  
 25 a fluorine atom, a chlorine atom, a bromine atom and an iodine  
 atom; an alkoxy group such as a methoxy group and an ethoxy  
 group; an aryloxy group such as a phenoxy group; or an aralkyloxy  
 group such as a benzyloxy group.

Examples of the hydrocarbon group are an alkyl group  
 30 having 1 to 20 carbon atoms such as a methyl group, an ethyl

group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, a tert-butyl group, an isobutyl group, a n-pentyl group, a n-hexyl group and a cyclohexyl group; an aryl group having 6 to 10 carbon atoms such as a phenyl group; and an aralkyl group having 7 to 10 carbon atoms such as a benzyl group. Examples of the silyl group are a trimethylsilyl group and a tert-butyldimethylsilyl group. Examples of such a di-substituted amino group are a dimethylamino group, a diethylamino group, a di-n-propylamino group, a diisopropylamino group, a di-n-butylamino group, a di-sec-butylamino group, a di-tert-butylamino group, a di-isobutylamino group, a tert-butylisopropylamino group, a di-n-hexylamino group, a di-n-octylamino group, a diphenylamino group, a bistrimethylsilylamino group and a bis-tert-butyldimethylsilylamino group; and a dimethylamino group, an diethylamino group, a diisopropylamino group, a di-tert-butylamino group or a bis-trimethylsilylamino group is preferred.

Examples of the hydrocarbon thio group in  $X^4$  to  $X^7$ ,  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] are an alkylthio group, an aralkylthio group and arylthio group.

Examples of the alkylthio group are a methylthio group, an ethylthio group, a n-propylthio group, an isopropylthio group, a n-butylthio group, a sec-butylthio group, a tert-butylthio group, a n-pentylthio group, a neopentylthio group, a n-hexylthio group, a n-octylthio group, a n-dodecylthio group, a n-pentadecylthio group and a n-eicosylthio group.

The alkylthio group is preferably an alkylthio group

having 1 to 20 carbon atoms, and more preferably a methylthio group, an ethylthio group, an isopropylthio group or a tert-butylthio group.

Examples of the aralkylthio group are a benzylthio group,

5 a (2-methylphenyl)methylthio group, a  
 (3-methylphenyl)methylthio group, a  
 (4-methylphenyl)methylthio group, a  
 (2,3-dimethylphenyl)methylthio group, a  
 (2,4-dimethylphenyl)methylthio group, a  
 10 (2,5-dimethylphenyl)methylthio group, a  
 (2,6-dimethylphenyl)methylthio group, a  
 (3,4-dimethylphenyl)methylthio group, a  
 (3,5-dimethylphenyl)methylthio group, a  
 (2,3,4-trimethylphenyl)methylthio group, a  
 15 (2,3,5-trimethylphenyl)methylthio group, a  
 (2,3,6-trimethylphenyl)methylthio group, a  
 (2,4,5-trimethylphenyl)methylthio group, a  
 (2,4,6-trimethylphenyl)methylthio group, a  
 (3,4,5-trimethylphenyl)methylthio group, a  
 20 (2,3,4,5-tetramethylphenyl)methylthio group, a  
 (2,3,4,6-tetramethylphenyl)methylthio group, a  
 (2,3,5,6-tetramethylphenyl)methylthio group, a  
 (pentamethylphenyl)methylthio group, an  
 (ethylphenyl)methylthio group, a (n-propylphenyl)methylthio  
 25 group, an (isopropylphenyl)methylthio group, a  
 (n-butylphenyl)methylthio group, a  
 (sec-butylphenyl)methylthio group, a  
 (tert-butylphenyl)methylthio group, a  
 (n-hexylphenyl)methylthio group, a (n-octylphenyl)methylthio  
 30 group, a (n-decylphenyl)methylthio group, a

naphthylmethylthio group and an anthracenylmethylthio group.

The aralkylthio group is preferably an aralkylthio group having 7 to 20 carbon atoms, and more preferably a benzylthio group.

5           Examples of the arylthio group are a phenylthio group, a 2-methylphenylthio group, a 3-methylphenylthio group, a 4-methylphenylthio group, a 2,3-dimethylphenylthio group, a 2,4-dimethylphenylthio group, a 2,5-dimethylphenylthio group, a 2,6-dimethylphenylthio group, a 3,4-dimethylphenylthio  
10           group, a 3,5-dimethylphenylthio group, a 2-tert-butyl-3-methylphenylthio group, a 2-tert-butyl-4-methylphenylthio group, a 2-tert-butyl-5-methylphenylthio group, a 2-tert-butyl-6-methylphenylthio group, a  
15           2,3,4-trimethylphenylthio group, a 2,3,5-trimethylphenylthio group, a 2,3,6-trimethylphenylthio group, a 2,4,5-trimethylphenylthio group, a 2,4,6-trimethylphenylthio group, a 2-tert-butyl-3,4-dimethylphenylthio group, a 2-tert-butyl-3,5-dimethylphenylthio group, a  
20           2-tert-butyl-3,6-dimethylphenylthio group, a 2,6-di-tert-butyl-3-methylphenylthio group, a 2-tert-butyl-4,5-dimethylphenylthio group, a 2,6-di-tert-butyl-4-methylphenylthio group, a 3,4,5-trimethylphenylthio group, a  
25           2,3,4,5-tetramethylphenylthio group, a 2,3,4,6-tetramethylphenylthio group, a 2-tert-butyl-3,4,6-trimethylphenylthio group, a 2,6-di-tert-butyl-3,4-dimethylphenylthio group, a 2,3,5,6-tetramethylphenylthio group, a  
30           2-tert-butyl-3,5,6-trimethylphenylthio group, a

2,6-di-tert-butyl-3,5-dimethylphenylthio group, a pentamethylphenylthio group, an ethylphenylthio group, a n-propylphenylthio group, an isopropylphenylthio group, a n-butylphenylthio group, a sec-butylphenylthio group, a  
 5 tert-butylphenylthio group, a n-pentylphenylthio group, a neopentylphenylthio group, a n-hexylphenylthio group, a n-octylphenylthio group, a n-decylphenylthio group, a n-tetradecylphenylthio group, a naphthylthio group and an anthracenylthio group.

10 The arylthio group is preferably an arylthio group having 6 to 20 carbon atoms.

Further, these alkylthio, aralkylthio and arylthio groups above-mentioned may be respectively substituted with a halogen atom such as a fluorine atom, a chlorine atom, a  
 15 bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; an aryloxy group such as a phenoxy group; or an aralkyloxy group such as a benzyloxy group.

Examples of the hydrocarbon seleno group in  $X^4$  to  $X^7$ ,  
 20  $R^{11}$  to  $R^{16}$ ,  $R^{21}$  to  $R^{26}$ ,  $R^{31}$  to  $R^{36}$ ,  $R^{61}$  to  $R^{66}$  and  $R^{71}$  to  $R^{76}$  of the formulas [8] to [10] are an alkylseleno group, an aralkylseleno group and an arylseleno group.

Examples of the alkylseleno group are a methylseleno group, an ethylseleno group, a n-propylseleno group, an  
 25 isopropylseleno group, a n-butylseleno group, a sec-butylseleno group, a tert-butylseleno group, a n-pentylseleno group, a neopentylseleno group, a n-hexylseleno group, a n-octylseleno group, a n-dodecylseleno group, a n-pentadecylseleno group and a n-eicosylseleno group.

30 The alkylseleno group is preferably an alkylseleno group

having 1 to 20 carbon atoms, and more preferably a methylseleno group, an ethylseleno group, an isopropylseleno group or a tert-butylseleno group.

Examples of the aralkylseleno group are a benzylseleno group, a (2-methylphenyl)methylseleno group, a (3-methylphenyl)methylseleno group, a (4-methylphenyl)methylseleno group, a (2,3-dimethylphenyl)methylseleno group, a (2,4-dimethylphenyl)methylseleno group, a (2,5-dimethylphenyl)methylseleno group, a (2,6-dimethylphenyl)methylseleno group, a (3,4-dimethylphenyl)methylseleno group, a (3,5-dimethylphenyl)methylseleno group, a (2,3,4-trimethylphenyl)methylseleno group, a (2,3,5-trimethylphenyl)methylseleno group, a (2,3,6-trimethylphenyl)methylseleno group, a (2,4,5-trimethylphenyl)methylseleno group, a (2,4,6-trimethylphenyl)methylseleno group, a (3,4,5-trimethylphenyl)methylseleno group, a (2,3,4,5-tetramethylphenyl)methylseleno group, a (2,3,4,6-tetramethylphenyl)methylseleno group, a (2,3,5,6-tetramethylphenyl)methylseleno group, a (pentamethylphenyl)methylseleno group, an (ethylphenyl)methylseleno group, a (n-propylphenyl)methylseleno group, an (isopropylphenyl)methylseleno group, a (n-butylphenyl)methylseleno group, a (sec-butylphenyl)methylseleno group, a (tert-butylphenyl)methylseleno group, a (n-hexylphenyl)methylseleno group, a

(n-octylphenyl)methylseleno group, a  
 (n-decylphenyl)methylseleno group, a naphthylmethylseleno  
 group and an anthracenylmethylseleno group.

The aralkylseleno group is preferably an aralkylseleno  
 5 group having 7 to 20 carbon atoms, and more preferably a  
 benzylseleno group.

Examples of the arylseleno group are a phenylseleno group,  
 a 2-methylphenylseleno group, a 3-methylphenylseleno group,  
 a 4-methylphenylseleno group, a 2,3-dimethylphenylseleno  
 10 group, a 2,4-dimethylphenylseleno group, a  
 2,5-dimethylphenylseleno group, a 2,6-dimethylphenylseleno  
 group, a 3,4-dimethylphenylseleno group, a  
 3,5-dimethylphenylseleno group, a  
 2-tert-butyl-3-methylphenylseleno group, a  
 15 2-tert-butyl-4-methylphenylseleno group, a  
 2-tert-butyl-5-methylphenylseleno group, a  
 2-tert-butyl-6-methylphenylseleno group, a  
 2,3,4-trimethylphenylseleno group, a  
 2,3,5-trimethylphenylseleno group, a  
 20 2,3,6-trimethylphenylseleno group, a  
 2,4,5-trimethylphenylseleno group, a  
 2,4,6-trimethylphenylseleno group, a  
 2-tert-butyl-3,4-dimethylphenylseleno group, a  
 2-tert-butyl-3,5-dimethylphenylseleno group, a  
 25 2-tert-butyl-3,6-dimethylphenylseleno group, a  
 2,6-di-tert-butyl-3-methylphenylseleno group, a  
 2-tert-butyl-4,5-dimethylphenylseleno group, a  
 2,6-di-tert-butyl-4-methylphenylseleno group, a  
 3,4,5-trimethylphenylseleno group, a  
 30 2,3,4,5-tetramethylphenylseleno group, a



2,3,4,6-tetramethylphenylseleno group, a  
 2-tert-butyl-3,4,6-trimethylphenylseleno group, a  
 2,6-di-tert-butyl-3,4-dimethylphenylseleno group, a  
 2,3,5,6-tetramethylphenylseleno group, a  
 5 2-tert-butyl-3,5,6-trimethylphenylseleno group, a  
 2,6-di-tert-butyl-3,5-dimethylphenylseleno group, a  
 pentamethylphenylseleno group, an ethylphenylseleno group,  
 a n-propylphenylseleno group, an isopropylphenylseleno group,  
 a n-butylphenylseleno group, a sec-butylphenylseleno group,  
 10 a tert-butylphenylseleno group, a n-pentylphenylseleno group,  
 a neopentylphenylseleno group, a n-hexylphenylseleno group,  
 a n-octylphenylseleno group, a n-decylphenylseleno group, a  
 n-tetradecylphenylseleno group, a naphthylseleno group and  
 an anthracenylseleno group.

15 The arylseleno group is preferably an alkylseleno group  
 having 6 to 20 carbon atoms.

These alkylseleno, aralkylseleno and arylseleno groups  
 above-mentioned may be respectively substituted with a halogen  
 atom such as a fluorine atom, a chlorine atom, a bromine atom  
 20 and an iodine atom; an alkoxy group such as a methoxy group  
 and an ethoxy group; an aryloxy group such as a phenoxy group;  
 or an aralkyloxy group such as a benzyloxy group.

$X^4$  to  $X^7$  in the formulas [8] to [10] are preferably  
 independently a halogen atom, an alkyl group, an aralkyl group,  
 25 an alkoxy group, an aryloxy group or a di-substituted amino  
 group, and more preferably a halogen atom, an alkyl group,  
 an alkoxy group or an aryloxy group.

Further,  $R^{11}$  to  $R^{14}$ ,  $R^{21}$  to  $R^{24}$ ,  $R^{31}$  to  $R^{34}$ ,  $R^{61}$  to  $R^{64}$  and  
 $R^{71}$  to  $R^{74}$  in the formula [8] to [10] are preferably independently  
 30 a hydrogen atom, a halogen atom, an alkyl group, an aralkyl

group, an aryl group, a substituted silyl group, an alkoxy group, an aralkyloxy group or an aryloxy group, and particularly,  $R^{11}$ ,  $R^{21}$ ,  $R^{31}$ ,  $R^{61}$  and  $R^{71}$  are preferably independently an alkyl group, an aralkyl group, an aryl group or a substituted silyl group.

Furthermore,  $R^{15}$ ,  $R^{16}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{35}$ ,  $R^{36}$ ,  $R^{65}$ ,  $R^{66}$ ,  $R^{75}$  and  $R^{76}$  are preferably independently a hydrogen atom, an alkyl group, an aralkyl group, an aryl group, a substituted silyl group, an alkoxy group, an aralkyloxy group or an aryloxy group.

Moreover,  $X^8$  to  $X^{10}$  in the formulas [9] and [10] are an atom of the Group 16 of the periodic table of the elements such as an oxygen atom, a sulfur atom and a selenium atom, and are preferably an oxygen atom or a sulfur atom, and more preferably an oxygen atom.

Furthermore,  $A^1$  to  $A^5$  in the formulas [8] to [10] are an atom of the Group 16 of the periodic table of the elements such as an oxygen atom, a sulfur atom and a selenium atom, and are preferably an oxygen atom.

Moreover,  $J^1$  to  $J^5$  in the formulas [8] to [10] are an atom of the Group 14 of the periodic table of the elements such as a carbon atom, a silicon atom and a germanium atom, and are preferably a carbon atom or a silicon atom.

Examples of the metal compound represented by the formula [8] are methylene( $\eta^5$ -cyclopentadienyl) (3,5-dimethyl-2-phenoxy)titanium dichloride (herein-after, " $\eta^5$ -" is sometimes omitted), methylene(cyclopentadienyl)(3-tert-butyl-2-phenoxy)titanium dichloride, methylene(cyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride,

methylene(cyclopentadienyl)(3-phenyl-2-phenoxy)titanium  
dichloride,

methylene(cyclopentadienyl)(3-tert-butyl dimethylsilyl-5-  
methyl-2-phenoxy)titanium dichloride,

5 methylene(cyclopentadienyl)(3-trimethylsilyl-5-methyl-2-  
phenoxy)titanium dichloride,

methylene(cyclopentadienyl)(3-tert-butyl-5-methoxy-2-  
phenoxy)titanium dichloride,

10 methylene(cyclopentadienyl)(3-tert-butyl-5-chloro-2-  
phenoxy)titanium dichloride,

methylene(tetramethylcyclopentadienyl)(3,5-dimethyl-2-  
phenoxy)titanium dichloride,

methylene(tetramethylcyclopentadienyl)(3-tert-butyl-2-  
phenoxy)titanium dichloride,

15 methylene(tetramethylcyclopentadienyl)(3-tert-butyl-5-  
methyl-2-phenoxy)titanium dichloride,

methylene(tetramethylcyclopentadienyl)(3-phenyl-2-  
phenoxy)titanium dichloride,

20 methylene(tetramethylcyclopentadienyl)(3-tert-butyl  
dimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

methylene(tetramethylcyclopentadienyl)  
(3-trimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

methylene(tetramethylcyclopentadienyl)  
(3-tert-butyl-5-methoxy-2-phenoxy)titanium dichloride,

25 methylene(tetramethylcyclopentadienyl)  
(3-tert-butyl-5-chloro-2-phenoxy)titanium dichloride,

isopropylidene(cyclopentadienyl)(3,5-dimethyl-2-phenoxy)  
titanium dichloride,

isopropylidene(cyclopentadienyl)(3-tert-butyl-2-phenoxy)

30 titanium dichloride,

isopropylidene(cyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride,

isopropylidene(cyclopentadienyl)(3-phenyl-2-phenoxy)titanium dichloride,

5 isopropylidene(cyclopentadienyl)(3-tert-butyl dimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

isopropylidene(cyclopentadienyl)(3-trimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

10 isopropylidene(cyclopentadienyl)(3-tert-butyl-5-methoxy-2-phenoxy)titanium dichloride,

isopropylidene(cyclopentadienyl)(3-tert-butyl-5-chloro-2-phenoxy)titanium dichloride,

isopropylidene(tetramethylcyclopentadienyl)(3,5-dimethyl-2-phenoxy)titanium dichloride,

15 isopropylidene(tetramethylcyclopentadienyl)(3-tert-butyl-2-phenoxy)titanium dichloride,

isopropylidene(tetramethylcyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride,

20 isopropylidene(tetramethylcyclopentadienyl)(3-phenyl-2-phenoxy)titanium dichloride,

isopropylidene(tetramethylcyclopentadienyl)(3-tert-butyl dimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

isopropylidene(tetramethylcyclopentadienyl)

(3-trimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

25 isopropylidene(tetramethylcyclopentadienyl)(3-tert-butyl-5-methoxy-2-phenoxy)titanium dichloride,

isopropylidene(tetramethylcyclopentadienyl)(3-tert-butyl-5-chloro-2-phenoxy)titanium dichloride,

30 diphenylmethylenecyclopentadienyl)(3,5-dimethyl-2-phenoxy)titanium dichloride,

diphenylmethylene(cyclopentadienyl)(3-tert-butyl-2-phenoxy)titanium dichloride,

diphenylmethylene(cyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride,

5 diphenylmethylene(cyclopentadienyl)(3-phenyl-2-phenoxy)titanium dichloride,

diphenylmethylene(cyclopentadienyl)(3-tert-butyldimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

10 diphenylmethylene(cyclopentadienyl)(3-trimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

diphenylmethylene(cyclopentadienyl)(3-tert-butyl-5-methoxy-2-phenoxy)titanium dichloride,

diphenylmethylene(cyclopentadienyl)(3-tert-butyl-5-chloro-2-phenoxy)titanium dichloride,

15 diphenylmethylene(tetramethylcyclopentadienyl)(3,5-dimethyl-2-phenoxy)titanium dichloride,

diphenylmethylene(tetramethylcyclopentadienyl)(3-tert-butyl-2-phenoxy)titanium dichloride,

20 diphenylmethylene(tetramethylcyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride,

diphenylmethylene(tetramethylcyclopentadienyl)(3-phenyl-2-phenoxy)titanium dichloride,

diphenylmethylene(tetramethylcyclopentadienyl)(3-tert-butyldimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

25 diphenylmethylene(tetramethylcyclopentadienyl)(3-trimethylsilyl-5-methyl-2-phenoxy)titanium dichloride,

diphenylmethylene(tetramethylcyclopentadienyl)(3-tert-butyl-5-methoxy-2-phenoxy)titanium dichloride, and

30 diphenylmethylene(tetramethylcyclopentadienyl)(3-tert-butyl-5-chloro-2-phenoxy)titanium dichloride; and compounds

in which " $(\eta^5\text{-cyclopentadienyl})$ " in the above-mentioned compounds is replaced with " $(\eta^5\text{-methylcyclopentadienyl})$ ", " $(\eta^5\text{-dimethylcyclopentadienyl})$ ", " $(\eta^5\text{-trimethylcyclopentadienyl})$ ", " $(\eta^5\text{-n-butylcyclopentadienyl})$ ", " $(\eta^5\text{-tert-butylcyclopentadienyl})$ ", " $(\eta^5\text{-trimethylsilylcyclopentadienyl})$ ", " $(\eta^5\text{-tert-butyl dimethylsilylcyclopentadienyl})$ ", " $(\eta^5\text{-indenyl})$ ", " $(\eta^5\text{-phenylindenyl})$ " or " $(\eta^5\text{-fluorenyl})$ ".

Further, compounds in which "dichloride" in the above-mentioned compounds is replaced with "dimethyl", "dibenzyl", "dimethoxide", "diphenoxide", "bis(dimethylamino)" or "bis(diethylamino)" are also exemplified.

Moreover, examples of the metal compound represented by the formula [8] are dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3-methyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3,5-dimethyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3-tert-butyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3-tert-butyl-5-methyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3,5-di-tert-butyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (5-methyl-3-phenyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (3-tert-butyl dimethylsilyl-5-methyl-2-phenoxy)titanium dichloride, dimethylsilylene ( $\eta^5\text{-cyclopentadienyl}$ ) (5-methyl-3-

trimethylsilyl-2-phenoxy)titanium dichloride,  
 dimethylsilylene( $\eta^5$ -cyclopentadienyl)(3-tert-butyl-5-  
 methoxy-2-phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -cyclopentadienyl)(3-tert-butyl-5-chloro-2-phenoxy)  
 5 titanium dichloride, dimethylsilylene( $\eta^5$ -cyclopentadienyl)  
 (3,5-diamyl-2-phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -cyclopentadienyl)(1-naphthoxy-2-yl)titanium dichloride,  
 dimethylsilylene( $\eta^5$ -tetramethylcyclopentadienyl)(2-  
 phenoxy)titanium dichloride, dimethylsilylene  
 10 ( $\eta^5$ -tetramethylcyclopentadienyl)(3-methyl-2-phenoxy)  
 titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3,5-dimethyl-2-phenoxy)  
 titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3-tert-butyl-2-phenoxy)  
 15 titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3-tert-butyl-5-methyl-2-  
 phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3,5-di-tert-butyl-2-  
 phenoxy)titanium dichloride, dimethylsilylene  
 20 ( $\eta^5$ -tetramethylcyclopentadienyl)(5-methyl-3-phenyl-2-  
 phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta$ -tetramethylcyclopentadienyl)(3-tert-butyl dimethylsilyl  
 -5-methyl-2-phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta$ -tetramethylcyclopentadienyl)(5-methyl-3-trimethylsilyl  
 25 -2-phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3-tert-butyl-5-methoxy  
 -2-phenoxy)titanium dichloride, dimethylsilylene  
 ( $\eta^5$ -tetramethylcyclopentadienyl)(3-tert-butyl-5-chloro-2-  
 phenoxy)titanium dichloride, dimethylsilylene  
 30 ( $\eta^5$ -tetramethylcyclopentadienyl)(3,5-diamyl-2-phenoxy)

titanium dichloride, and dimethylsilylene  
 ( $\eta^5$ -cyclopentadienyl)(1-naphtoxy-2-yl)titanium dichloride;  
 and compounds in which " $(\eta^5$ -cyclopentadienyl)" in the  
 above-mentioned compounds is replaced with

5 " $(\eta^5$ -methylcyclopentadienyl)",

" $(\eta^5$ -dimethylcyclopentadienyl)",

" $(\eta^5$ -trimethylcyclopentadienyl)",

" $(\eta^5$ -n-butylcyclopentadienyl)",

" $(\eta^5$ -tert-butylcyclopentadienyl)",

10 " $(\eta^5$ -trimethylsilylcyclopentadienyl)",

" $(\eta^5$ -tert-butyldimethylsilylcyclopentadienyl)",

" $(\eta^5$ -indenyl)", " $(\eta^5$ -phenylindenyl)" or " $(\eta^5$ -fluorenyl)";

compounds in which "(2-phenoxy)" in the above-mentioned  
 compounds is replaced with "3-phenyl-2-phenoxy",

15 "3-trimethylsilyl-2-phenoxy" or

"3-tert-butyldimethylsilyl-2-phenoxy"; and compounds in

which "dimethylsilylene" in the above-mentioned compounds is  
 replaced with "diethylsilylene", "diphenylsilylene" or

"dimethoxysilylene". Further, compounds in which "dichloride"

20 in the above-mentioned compounds is replaced with "dimethyl",

"dibenzyl", "dimethoxide", "diphenoxide",

"bis(dimethylamino)" or "bis(diethylamino)" are also

exemplified. Furthermore, compounds in which "titanium" in

the above-mentioned compounds is replaced with "zirconium"

25 or "hafnium" are exemplified.

Moreover, in the metal compound represented by the  
 formula [9], specific examples of the  $\mu$ -oxo type compound are

$\mu$ -oxobis{isopropylidene(cyclopentadienyl)}

(2-phenoxy)titanium chloride},

30  $\mu$ -oxobis{isopropylidene(cyclopentadienyl)}(2-phenoxy)



titanium methoxide},  $\mu$ -oxobis{isopropylidene  
 (cyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)  
 titanium chloride},  $\mu$ -oxobis{isopropylidene  
 (cyclopentadienyl) (3-tert-butyl-5-methyl-2-phenoxy)  
 5 titanium methoxide},  $\mu$ -oxobis{isopropylidene  
 (methylcyclopentadienyl)(2-phenoxy)titanium chloride},  
 $\mu$ -oxobis{isopropylidene (methylcyclopentadienyl)  
 (2-phenoxy)titanium methoxide},  $\mu$ -oxobis{isopropylidene  
 (methylcyclopentadienyl) (3-tert-butyl-5-methyl-2-  
 10 phenoxy)titanium chloride},  $\mu$ -oxobis{isopropylidene  
 (methylcyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)  
 titanium methoxide},  $\mu$ -oxobis{isopropylidene  
 (tetramethylcyclopentadienyl) (2-phenoxy)titanium chloride},  
 $\mu$ -oxobis{isopropylidene(tetramethylcyclopentadienyl)(2-  
 15 phenoxy)titanium methoxide},  $\mu$ -oxobis{isopropylidene  
 (tetramethylcyclopentadienyl)(3-tert-butyl-5-methyl-2-  
 phenoxy)titanium chloride}, and  $\mu$ -oxobis{isopropylidene  
 (tetramethylcyclopentadienyl) (3-tert-butyl-5-methyl-2-  
 phenoxy)titanium methoxide}; and compounds in which "( $\eta$   
 20  $^5$ -cyclopentadienyl)" in the above-mentioned compounds is  
 replaced with "( $\eta$  $^5$ -dimethylcyclopentadienyl)",  
 "( $\eta$  $^5$ -trimethylcyclopentadienyl)",  
 "( $\eta$  $^5$ -n-butylcyclopentadienyl)",  
 "( $\eta$  $^5$ -tert-butylcyclopentadienyl)",  
 25 "( $\eta$  $^5$ -trimethylsilylcyclopentadienyl)",  
 "( $\eta$  $^5$ -tert-butyltrimethylsilylcyclopentadienyl)",  
 "( $\eta$  $^5$ -indenyl)", "( $\eta$  $^5$ -methylindenyl)" or "( $\eta$  $^5$ -fluorenyl)".  
 Further, compounds in which "(2-phenoxy)" in the  
 above-mentioned compounds is replaced with " (3-methyl-2-  
 30 phenoxy)", "(3,5-dimethyl-2-phenoxy)", "(3,5-di-tert-butyl

-2-phenoxy)", "(3-phenyl-5-methyl--2-phenoxy)" or  
 "(3-trimethylsilyl-5-methyl-2-phenoxy)" and compounds in  
 which "chloride" in the above-mentioned compounds is replaced  
 with "methyl", "benzyl", "phenoxide", "dimethylamino" or  
 5 "diethylamino" are also exemplified. Furthermore, compounds  
 in which "titanium" in the above-mentioned compounds is  
 replaced with "zirconium" or "hafnium" are exemplified.

Moreover, in the metal compound represented by the  
 formula [10], specific examples of the  $\mu$ -oxo type compound  
 10 are di- $\mu$ -oxobis[isopropylidene  
 (cyclopentadienyl) (2-phenoxy)titanium], di- $\mu$ -oxobis  
 [isopropylidene(cyclopentadienyl)(3-tert-butyl-5-methyl-2  
 -phenoxy)titanium], di- $\mu$ -oxobis[isopropylidene  
 (methylcyclopentadienyl)(2-phenoxy)titanium], di- $\mu$ -oxobis  
 15 [isopropylidene(methylcyclopentadienyl)(3-tert-butyl-5-  
 methyl-2-phenoxy)titanium], di- $\mu$ -oxobis[isopropylidene  
 (tetramethylcyclopentadienyl)(2-phenoxy)titanium], di- $\mu$ -  
 -oxobis[isopropylidene (tetramethylcyclopentadienyl)  
 (3-tert-butyl-5-methyl-2-phenoxy)titanium], di- $\mu$ -oxobis  
 20 [dimethylsilylene(cyclopentadienyl)(2-phenoxy)titanium],  
 di- $\mu$ -oxobis[dimethylsilylene(cyclopentadienyl) (3-tert-  
 butyl-5-methyl-2-phenoxy)titanium], di- $\mu$ -oxobis  
 [dimethylsilylene(methylcyclopentadienyl)(2-phenoxy)  
 titanium], di- $\mu$ -oxobis[dimethylsilylene  
 25 (methylcyclopentadienyl)(3-tert-butyl-5-methyl-2-phenoxy)  
 titanium], di- $\mu$ -oxobis[dimethylsilylene  
 (tetramethylcyclopentadienyl)(2-phenoxy)titanium], and di-  
 $\mu$ -oxobis[dimethylsilylene(tetramethylcyclopentadienyl)(3-  
 tert-butyl-5-methyl-2-phenoxy)titanium]; and compounds in  
 30 which "( $\eta^5$ -cyclopentadienyl)" in the above-mentioned compounds

is replaced with " $(\eta^5\text{-dimethylcyclopentadienyl})$ ",  
 " $(\eta^5\text{-trimethylcyclopentadienyl})$ ",  
 " $(\eta^5\text{-n-butylcyclopentadienyl})$ ",  
 " $(\eta^5\text{-tert-butylcyclopentadienyl})$ ",  
 5 " $(\eta^5\text{-trimethylsilylcyclopentadienyl})$ ",  
 " $(\eta^5\text{-tert-butyl dimethylsilylcyclopentadienyl})$ ",  
 " $(\eta^5\text{-indenyl})$ ", " $(\eta^5\text{-methylindenyl})$ " or " $(\eta^5\text{-fluorenyl})$ ".  
 Further, compounds in which " $(2\text{-phenoxy})$ " in the above-mentioned  
 compounds is replaced with " $(3\text{-methyl-2-phenoxy})$ ",  
 10 " $(3,5\text{-dimethyl-2-phenoxy})$ ",  
 " $(3,5\text{-di-tert-butyl-2-phenoxy})$ ",  
 " $(3\text{-phenyl-5-methyl-2-phenoxy})$ " or  
 " $(3\text{-trimethylsilyl-5-methyl-2-phenoxy})$ ". Furthermore,  
 compounds in which "titanium" in the above-mentioned compounds  
 15 is replaced with "zirconium" or "hafnium" are exemplified.

The above-mentioned metal compounds as the compound (B)  
 may be used singly, or may be used in combination of two or  
 more thereof.

The compound (B) is preferably a metal compound  
 20 represented by the formula [4], more preferably a metal compound  
 in which  $M^2$  in the formula [4] is the Group 4 atom in the periodic  
 table, and further preferably a metal compound, which contains  
 at least one group having a cyclopentadienyl type anion skeleton  
 as  $L^2$  in the formula [4].

25 As the organoaluminum compound (C) used for the catalyst  
 for addition polymerization according to the present invention,  
 known organoaluminum compounds can be used. Preferred is an  
 organoaluminum compound represented by the following formula  
 [11]:



wherein  $d$  is a number satisfying  $0 < d \leq 3$ ;  $R^6$  is a hydrocarbon group, and when two or more  $R^6$  groups exist, these may be the same or different;  $Y$  is a hydrogen atom, a halogen atom or an hydrocarbonoxy group, and when two or more  $Y$ 's exist, they may be the same or different.

$R^6$  in the formula [11] is preferably a hydrocarbon group having 1 to 24 carbon atoms, and more preferably an alkyl group having 1 to 24 carbon atoms. Examples thereof are a methyl group, an ethyl group, a *n*-propyl group, a *n*-butyl group, an isobutyl group, a *n*-hexyl group, a 2-methylhexyl group and a *n*-octyl group. More preferred is an ethyl group, a *n*-butyl group, an isobutyl group, a *n*-hexyl group or a *n*-octyl group.

Examples of the halogen atom as  $Y$  in the formula [11] are a fluorine atom, a chlorine atom, a bromine atom and an iodine atom, and preferred is a chlorine atom.

The hydrocarbonoxy group as  $Y$  in the formula [11] is preferably an alkoxy group, an aralkyloxy group or an aryloxy group.

Examples of the alkoxy group as  $Y$  in the formula [11] are a methoxy group, an ethoxy group, a *n*-propoxy group, an isopropoxy group, a *n*-butoxy group, a *sec*-butoxy group, a *tert*-butoxy group, a *n*-pentoxy group, a neopentoxy group, a *n*-hexoxy group, a *n*-octoxy group, a *n*-dodecoxy group, a *n*-pentadecoxy group and a *n*-icosoxy group.

Each of those alkoxy groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; or an aryloxy group such as a phenoxy

group.

The alkoxy group as Y in the formula [11] is preferably an alkoxy group having 1 to 24 carbon atoms, and more preferably a methoxy group, an ethoxy group or a tert-butoxy group.

5        Examples of the aryloxy group as Y in the formula [11] are a phenoxy group, a 2-methylphenoxy group, a 3-methylphenoxy group, a 4-methylphenoxy group, a 2,3-dimethylphenoxy group, a 2,4-dimethylphenoxy group, a 2,5-dimethylphenoxy group, a 2,6-dimethylphenoxy group, a 3,4-dimethylphenoxy group, a 10 3,5-dimethylphenoxy group, a 2,3,4-trimethylphenoxy group, a 2,3,5-trimethylphenoxy group, a 2,3,6-trimethylphenoxy group, a 2,4,5-trimethylphenoxy group, a 2,4,6-trimethylphenoxy group, a 3,4,5-trimethylphenoxy group, a 2,3,4,5-tetramethylphenoxy group, a 15 2,3,4,6-tetramethylphenoxy group, 2,3,5,6-tetramethylphenoxy group, a pentamethylphenoxy group, an ethylphenoxy group, a n-propylphenoxy group, an isopropylphenoxy group, a n-butylphenoxy group, a sec-butylphenoxy group, a tert-butylphenoxy group, a 20 n-hexylphenoxy group, a n-octylphenoxy group, a n-decylphenoxy group, a n-tetradecylphenoxy group, a naphthoxy group and an anthrathenoxy group.

Each of those aryloxy groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a 25 bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; or an aryloxy group such as a phenoxy group.

The aryloxy group as Y in the formula [11] is preferably an aryloxy group having 6 to 24 carbon atoms.

30        Examples of the aralkyloxy group as Y in the formula

[11] are a benzyloxy group, a (2-methylphenyl)methoxy group, a (3-methylphenyl)methoxy group, a (4-methylphenyl)methoxy group, a (2,3-dimethylphenyl)methoxy group, a (2,4-dimethylphenyl)methoxy group, a (2,5-dimethylphenyl)methoxy group, a (2,6-dimethylphenyl)methoxy group, a (3,4-dimethylphenyl)methoxy group, a (3,5-dimethylphenyl)methoxy group, a (2,3,4-trimethylphenyl)methoxy group, a (2,3,5-trimethylphenyl)methoxy group, a (2,3,6-trimethylphenyl)methoxy group, a (2,4,5-trimethylphenyl)methoxy group, a (2,4,6-trimethylphenyl)methoxy group, a (3,4,5-trimethylphenyl)methoxy group, a (2,3,4,5-tetramethylphenyl)methoxy group, a (2,3,4,6-tetramethylphenyl)methoxy group, a (2,3,5,6-tetramethylphenyl)methoxy group, a (pentamethylphenyl)methoxy group, an (ethylphenyl)methoxy group, a (n-propylphenyl)methoxy group, an (isopropylphenyl)methoxy group, a (n-butylphenyl)methoxy group, a (sec-butylphenyl)methoxy group, a (tert-butylphenyl)methoxy group, a (n-hexylphenyl)methoxy group, a (n-octylphenyl)methoxy group, a (n-decylphenyl)methoxy group, a (n-tetradecylphenyl)methoxy group, a naphthylmethoxy group and an anthrathenylmethoxy group.

Each of those aralkyloxy groups may be substituted with a halogen atom such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; an alkoxy group such as a methoxy group and an ethoxy group; or an aryloxy group such

as a phenoxy group.

The aralkyloxy group as Y in the formula [11] is preferably an aralkyloxy group having 7 to 24 carbon atoms, and more preferably a benzyloxy group.

5           Examples of the organoaluminum compound represented by the formula [11] are a trialkylaluminum such as trimethylaluminum, triethylaluminum, tri-n-propylaluminum, tri-n-butylaluminum, triisobutylaluminum, tri-n-hexylaluminum and tri-n-octylaluminum; a  
10   dialkylaluminum chloride such as dimethylaluminum chloride, diethylaluminum chloride, di-n-propylaluminum chloride, di-n-butylaluminum chloride, diisobutylaluminum chloride and di-n-hexylaluminum chloride; an alkylaluminum dichloride such as methylaluminum dichloride, ethylaluminum dichloride,  
15   n-propylaluminum dichloride, n-butylaluminum dichloride, isobutylaluminum dichloride and n-hexylaluminum dichloride; a dialkylaluminum hydride such as dimethylaluminum hydride, diethylaluminum hydride, di-n-propylaluminum hydride, di-n-butylaluminum hydride, diisobutylaluminum hydride and  
20   di-n-hexylaluminum hydride; an alkyl(dialkoxy)aluminum such as methyl(dimethoxy)aluminum, methyl(diethoxy)aluminum and methyl(di-tert-butoxy)aluminum; a dialkyl(alkoxy)aluminum such as dimethyl(methoxy)aluminum, dimethyl(ethoxy)aluminum and dimethyl(tert-butoxy)aluminum; an  
25   alkyl(diaryloxy)aluminum such as methyl(diphenoxy)aluminum, methylbis(2,6-diisopropylphenoxy)aluminum and methylbis(2,6-diphenylphenoxy)aluminum; and a dialkyl(aryloxy)aluminum such as dimethyl(phenoxy)aluminum, dimethyl(2,6-diisopropylphenoxy)aluminum and  
30   dimethyl(2,6-diphenylphenoxy)aluminum.

Among them, preferred is a trialkylaluminum, further preferred is trimethylaluminum, triethylaluminum, tri-n-butylaluminum, triisobutylaluminum or tri-n-hexylaluminum, and particularly preferred is triisobutylaluminum or tri-n-hexylaluminum.

These organoaluminum compounds may be used alone, or in combination of two or more thereof.

The ratio (molar ratio) of the amount of the respective catalyst components used in the present invention is not particularly limited. The molar ratio of the component (A) to the component (B) is usually in a range of (A) : (B) = from 1 : 1 to 10000 : 1, preferably from 1 : 1 to 5000 : 1, and further preferably from 1 : 1 to 1000 : 1. The amount of the component (C) is usually in a range of (B) : (C) = from 0.1 : 1 to 1 : 10000, and preferably from 1 : 1 to 1 : 1000.

As the catalyst for addition polymerization of the present invention, a reaction product obtained by preliminarily contacting the component (A) and the component (B), optionally, further the component (C) may be also used, and they may be also used by being separately charged in a polymerization vessel. The arbitrary two components among them may be also previously contacted, and further, another component may be also contacted.

Examples of the addition polymerizable monomer in the present invention are an olefin, a diolefin, a cyclic olefin, an alkenyl aromatic hydrocarbon and a polar monomer, each of which has 2 to 100 carbon atoms. A combination of two or more thereof may be used.

Examples thereof are an olefin such as ethylene, propylene, 1-butene, 1-pentene, 4-methyl-1-pentene-1,



5-methyl-1-hexene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene and vinylcyclohexane; a diolefin such as 1,5-hexadiene, 1,4-hexadiene, 1,4-pentadiene, 1,7-octadiene, 1,8-nonadiene, 1,9-decadiene, 4-methyl-1,4-hexadiene,

5 5-methyl-1,4-hexadiene, 7-methyl-1,6-octadiene, 5-ethylidene-2-norbornene, dicyclopentadiene, 5-vinyl-2-norbornene, 5-methyl-2-norbornene, norbornadiene, 5-methylene-2-norbornene, 1,5-cyclooctadiene, 5,8-endomethylenehexahydronaphthalene, 1,3-butadiene,

10 isoprene, 1,3-hexadiene, 1,3-octadiene, 1,3-cyclooctadiene and 1,3-cyclohexadiene; a cyclic olefin such as norbornene, 5-methylnorbornene, 5-ethylnorbornene, 5-butylnorbornene, 5-phenylnorbornene, 5-benzylnorbornene, tetracyclododecene, tricyclodecene, tricycloundecene, pentacyclopentadecene,

15 pentacyclohexadecene, 8-methyltetracyclododecene, 8-ethyltetracyclododecene, 5-acetylnorbornene, 5-acetyloxynorbornene, 5-methoxycarbonylnorbornene, 5-ethoxycarbonylnorbornene, 5-methyl-5-methoxycarbonylnorbornene, 5-cyanonorbornene,

20 8-methoxycarbonyltetracyclododecene, 8-methyl-8-tetracyclododecene and 8-cyanotetracyclododecene; an alkenyl aromatic hydrocarbon such as an alkenylbenzene (e.g. styrene, 2-phenylpropylene, 2-phenylbutene and 3-phenylpropylene), an alkylstyrene (e.g.

25 p-methylstyrene, m-methylstyrene, o-methylstyrene, p-ethylstyrene, m-ethylstyrene, o-ethylstyrene, 2,4-dimethylstyrene, 2,5-dimethylstyrene, 3,4-dimethylstyrene, 3,5-dimethylstyrene, 3-methyl-5-ethylstyrene, p-tert-butylstyrene and

30 p-sec-butylstyrene), a bis(alkenyl)benzene (e.g.

divinylbenzene) and an alkenylnaphthalene (e.g. 1-vinylnaphthalene); and a polar monomer such as an  $\alpha, \beta$ -unsaturated carboxylic acid (e.g. acrylic acid, methacrylic acid, fumaric acid, maleic anhydride, itaconic acid, itaconic anhydride and bicyclo(2,2,1)-5-heptene-2,3-dicarboxylic acid), and metal salts thereof (e.g. salts of sodium, potassium, lithium, zinc, magnesium and calcium), an  $\alpha, \beta$ -unsaturated carboxylic acid ester (e.g. methyl acrylate, ethyl acrylate, n-propyl acrylate, isopropyl acrylate, tert-butyl acrylate, 2-ethylhexyl acrylate, methyl methacrylate, ethyl methacrylate, n-propyl methacrylate, isopropyl methacrylate, n-butyl methacrylate and isobutyl methacrylate), an unsaturated dicarboxylic acid (e.g. maleic acid and itaconic acid), a vinyl ester (e.g. vinyl acetate, vinyl propionate, vinyl capronate, vinyl caprate, vinyl laurate, vinyl stearate and vinyl trifluoroacetate), an unsaturated carboxylic acid glycidylate (e.g. acrylic acid glycidylate, methacrylic acid glycidylate and itaconic acid monoglycidylate), and a cyclic ether (e.g. ethylene oxide, propylene oxide, 1-hexene oxide, cyclohexene oxide, styrene oxide and tetrahydrofuran).

The catalyst for addition polymerization of the present invention can be applied to homopolymerization or copolymerization of these monomers. Examples of a combination of monomers constituting the copolymer are ethylene and propylene; ethylene and 1-butene; ethylene and 1-hexene; and propylene and 1-butene.

The catalyst for olefin polymerization according to the present invention is particularly preferable as a catalyst for olefin polymerization, and is preferably used for a process for producing an olefin polymer. The olefin polymer is

particularly preferably copolymers of ethylene with an  $\alpha$ -olefin. Among them, preferred is a copolymer of ethylene with an  $\alpha$ -olefin having a polyethylene crystal structure. The  $\alpha$ -olefin has preferably 3 to 8 carbon atoms, and examples thereof are 1-butene, 1-hexene and 1-octene.

A polymerization method is not particularly limited. For example, there can be exemplified a solvent polymerization method and a slurry polymerization method, in which an aliphatic hydrocarbon (e.g. butane, pentane, hexane, heptane and octane), an aromatic hydrocarbon (e.g. benzene and toluene) or a halogenated hydrocarbon (e.g. methylene dichloride) is used as a solvent; a bulk polymerization method, in which polymerization is carried out in a liquid monomer; a gas phase polymerization method, in which polymerization is carried out in a gaseous monomer; and a high-pressure polymerization method, in which polymerization is carried out in a supercritical liquid condition at a high temperature under a high pressure. As a polymerization type, either of a batch-wise type and a continuous type is possible.

A method of feeding the respective components in a reactor is not particularly limited. Examples thereof are a method of feeding them in a solid condition; and a method of feeding them in a condition of a solution, a suspension or a slurry, using a hydrocarbon solvent, from which components deactivating catalyst components such as moisture and oxygen are completely removed,

When the respective components are used as a solution, the concentration of the component (A) and the component (C) are usually from 0.0001 to 100 mmol/L, and preferably from 0.01 to 10 mmol/L, converted to a metal atom, respectively.

The concentration of the component (B) is usually from 0.0001 to 100 mmol/L, and preferably from 0.01 to 10 mmol/L, converted to a metal atom.

The polymerization temperature is usually from -100 to 350°C, preferably from -20 to 300°C, and more preferably from 20 to 300°C. The polymerization pressure is usually from 0.1 to 350 MPa, preferably from 0.1 to 300 MPa, and more preferably from 0.1 to 200 MPa. In general, the polymerization time can be appropriately determined according to the kind of a desired polymer and a reaction apparatus, and a range of from 1 minute to 20 hours can be adopted.

In order to control a molecular weight of an addition polymer, a chain transfer agent such as hydrogen may be added.

## Examples

The present invention is further illustrated in detail according to Examples and Comparative Examples below, but the present invention is not limited thereto.

The measurement values of respective items in Examples were measured according to methods described below.

(1) Content of  $\alpha$ -olefin unit in copolymer (short chain branch degree : SCB)

The content of an  $\alpha$ -olefin unit in an obtained polymer was determined from an IR absorption spectrum, wherein the measurement and calculation were carried out by using characteristic absorptions derived from the  $\alpha$ -olefin, according to a method described in "Die Makromolekulare Chemie, 177, 449 (1976) McRae, M. A., Madams, W. F.", and the IR absorption spectrum was obtained by a measurement using an

infrared spectrometer (FT-IR7300, manufactured by NIPPON BUNKO Inc.).

(2) Intrinsic viscosity ( $[\eta]$ )

5 It was measured at 135°C in a tetralin solution using an Ubbelohde viscometer.

(3) Molecular weight and molecular weight distribution

They were determined under the under-mentioned  
10 conditions according to a gel permeation chromatography (GPC). A calibration curve was prepared using standard polystyrenes. Molecular weight distribution was evaluated by a ratio, (Mw/Mn), of a weight average molecular weight (Mw) to a number average molecular weight (Mn):

15 equipment: 150C type, manufactured by Millipore Waters Co., Ltd.,

column: TSK-GEL GMH-HT,  $7.5 \times 600 \times 2$  columns,

measurement temperature: 140°C,

solvent: o-dichlorobenzene, and

20 measurement concentration: 5 mg/5 ml.

(4) Melt flow rate (MFR) (g/10 min)

According to a method prescribed in JIS K7210-1995, it was measured at 190°C under a load of 21.18 N (2.16 kg). As  
25 a sample, a polymer containing 1000 ppm of an antioxidant was used.

Example 1

(1) Preparation of bismuth compound

30 Into a 300 ml four-necked flask purged with argon, 9.88

g (22.4 mmol) of triphenyl bismuth and 100 ml of toluene were charged, and the mixture was stirred at room temperature. Thereto, a solution of 12.6 g (68.5 mmol) of pentafluorophenol in 100 ml of toluene was added dropwise. Thereafter, the mixture was stirred for 15.5 hours at room temperature. Then, the reaction was carried out (i) for 4 hours under a toluene-refluxing condition, (ii) for 18 hour at room temperature, (iii) for 7 hours under a toluene-refluxing condition, and (iv) for 17 hour at room temperature. A formed yellow needle-like crystal was filtered, and dried under vacuum at room temperature, thereby obtaining 12.6 g of a yellow crystal (hereinafter, referred to as "compound A").

Next, into a 100ml four-necked flask purged with argon, 0.967 g (1.14 mmol) of the compound A and 30 ml of toluene were charged. Thereto, 0.243 g (1.13 mmol) of diphenylsilanediol and 10 ml of toluene were charged at room temperature. The mixture was stirred for 6 hours under a refluxing condition. By allowing the mixture to stand without stirring, a white precipitation was formed, and the supernatant liquid was a yellow clear liquid. A white crystal was obtained by distilling out volatile components under vacuum, and drying.

## (2) Production of addition polymer

After drying under vacuum an autoclave reactor having an inner volume of 400ml equipped with a stirrer, and replacing the atmosphere thereof with argon, 190 ml of hexane as a solvent and 10 ml of 1-hexene as a comonomer were charged, and the reactor was heated to 70 °C. Then, ethylene was fed while adjusting at an ethylene pressure of 0.6 MPa. After the system was stabilized, 0.25 ml (250  $\mu$ mol) of triisobutylaluminum (1

mmol/ml, toluene solution) was charged, successively, 0.5 ml (1  $\mu$ mol) of ethylenebis(indenyl)zirconium dichloride (2  $\mu$ mol/ml, toluene solution) was charged, and then, 43.3 mg of the white crystal obtained in the above (1) was charged. The polymerization was carried out at 70 °C for 30 minutes under feeding ethylene to keep the constant total pressure. As a result, 2.06 g of an ethylene-1-hexene copolymer was obtained. The polymerization activity, SCB, Mw and Mw/Mn were  $4.1 \times 10^6$  g/mol-Zr/hour, 15.5, 92000 and 2.5, respectively.

#### Comparative Example 1

Example 1 was repeated except that 43.3 mg of the white crystal used in Example 1 (2) was changed to 49.8 mg (113  $\mu$ mol) of triphenyl bismuth. As a result, only a trace of an ethylene-1-hexene copolymer was obtained.

#### Comparative Example 2

Example 1 was repeated except that 43.3 mg of the white crystal used in Example 1 (2) was changed to 60.9 mg (71.6  $\mu$ mol) of the compound A prepared in Example 1 (1). As a result, only a trace of an ethylene-1-hexene copolymer was obtained.

#### Comparative Example 3

##### (1) Preparation of bismuth compound

Into a 100 ml four-necked flask purged with argon, 1.06 g (1.25 mmol) of the compound A prepared in Example 1 (1) and 30 ml of toluene were charged. Thereto, 0.125 g (0.578 mmol) of diphenylsilanediol and 10 ml of toluene were charged at room temperature. The mixture was stirred for three hours under a refluxing condition. By allowing the mixture to stand

overnight at room temperature without stirring, a needle-like crystal was formed. The crystal was filtered, dried under vacuum, and 70.2 mg of the dried crystal was placed in another flask. Thereto, 10 ml of toluene was added to obtain a slurry.

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## (2) Production of addition polymer

Example 1 (2) was repeated except that 43.3 mg of the white crystal used therein was changed to 5 ml of the slurry obtained in the above (1). As a result, only a trace of an ethylene-1-hxene copolymer was obtained.

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## Example 2

### (1)

Into a 100 ml four-necked flask purged with nitrogen, 17.5 ml of toluene and 12.5 ml (25.0 mmol) of a toluene solution (2.00 mol/liter) of triethylaluminum were charged, and the mixture was cooled at 5 °C. Thereto, 3.5 ml (33.3 mmol) of 1,1,1,3,3,3-hexafluoro-2-propanol was added dropwise over 0.25 hour. Thereafter, the mixture was stirred for 1.5 hours at 5 °C. Then, 5.3 g (24.5 mmol) of diphenylsilanediol was added thereto. Thereafter, the mixture was stirred for 1 hour at 5 °C, for 1 hour at 40 °C, and for 2 hours at 80 °C, respectively, thereby obtaining a deep green-colored slurry solution, whose concentration was 0.75 mol/liter in terms of an aluminum atom based on the amount added.

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### (2) Polymerization

A 3 liter-inner volume autoclave reactor equipped with a stirrer was dried under reduced pressure, and the atmosphere thereof was replaced with argon, and then made vacuum. 1000

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ml of toluene and 30 g of 1-butene were charged thereto, and the reactor was heated to 70 °C. Thereafter, ethylene was fed while adjusting at an ethylene pressure of 0.6 MPa, and the system was stabilized. A gas chromatography analysis showed a 1-butene concentration in the system of 5.66 mol%. Thereto, 0.9 ml of a hexane solution (concentration = 1 mmol/ml) of triisobutylaluminum was charged. Next, 0.25 ml of a toluene solution (concentration = 2  $\mu$ mol/ml) of racemi-ethylenebis(1-indenyl)zirconium diphenoxide was charged, and successively, 0.6 ml of the slurry solution obtained in the above-mentioned Example 2 (1) was charged. The polymerization was carried out at 70 °C for 20 minutes under feeding ethylene to keep the constant total pressure. After deashing and washing with a hydrochloric acid/methanol solution, and then drying under vacuum, 49 g of an olefin polymer was obtained. The polymerization activity, SCB and MFR were  $2.9 \times 10^8$  g/mol-Zr/hour, 17.1 and 4.7, respectively.